Coastal stability in the South Taranaki Bight - Phase 1

Historical and present day shoreline change

Prepared for Trans-Tasman Resources Ltd

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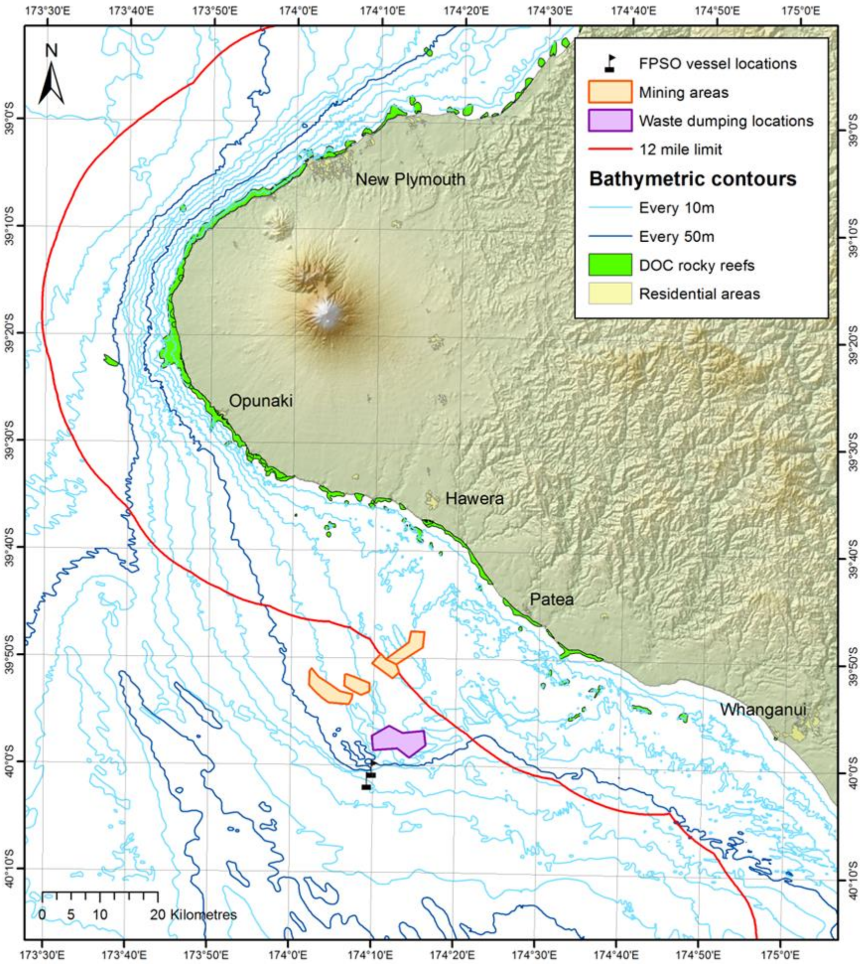
Executive summary

Trans-Tasman Resources Ltd (TTR) has secured permits and is prospecting for offshore iron sands in the South Taranaki Bight along the West Coast, North Island. At the time of writing this report (September 2012) the plan was for mining to involve dredging large depressions in the seabed, concentrating iron ore on board vessels and then returning the de-ored sand (tailings) to the seabed, where it will partially fill the depressions and also form mounds. Mining sites and areas where de-ored sand might be deposited are about 15 to 35 km offshore from Patea. Depressions and mounds on the seabed have the potential to alter the direction of wave approach and wave height at the shoreline and therefore longshore transport and patterns of erosion and accretion at the shoreline, depending on the scale of the operations.



This report (Phase 1 studies) provides an assessment of the stability of the shoreline of the South Taranaki Bight extending 130 km from about Opunake to Wanganui. It reviews the historical and present day rates of change in the position of the shoreline and temporal variations in sand storage on the beaches. This information, along with planned investigations of cross shore sediment exchange and longshore flux and sand transport in the proposed mining area (Phase 2 studies), will provide a context and scale against which to gauge the potential effects of the sand mining of the offshore seabed.

The assessment is based on a synthesis of information from: 1) a report on historical changes in shoreline position, 2) an 11-month record of beach profiles surveyed by NIWA for TTR to monitor the stability of the shoreline at eight beaches between Manaia and Wanganui and 3) other available information and theory of the regional geomorphology and coastal processes.

Historical shoreline change is used in this report to describe changes in shoreline position that have taken place over timescales of decades. The shoreline in the South Taranaki Bight contains sections of 30 – 50 m tall near-vertical cliffs which are fronted by small beaches in places and sections of beach backed by sand dunes. Shoreline as used in this report refers to either the toe of the cliffs or the mean high water spring (MHWS) tide level which is often estimated as the seaward boundary of vegetation when survey marks are not available.

The beach profile record from the South Taranaki Bight provides us with a picture of short-term changes at the time scale of months and storm events. A beach profile is a surveyed shore-normal line that runs down the beach, typically between the foredune and the safe wading limit at low tide. Comparison of repeat surveys (if repeated often enough) shows how the beach and dune face build up and cut down as sand moves on and off or along the beach in response to waves and wind, how the shoreline moves in and out, the amount of sand moving on and off the beach and the frequency of those sand exchanges. Profile data is a record of the temporal variations in sand storage above high tide and intertidal beach areas, and not a measurement of cross-shore sediment exchange or alongshore flux in the surf zone. Beach profile measurements consider the site-specific response to local marine conditions and the sedimentary environment.

NIWA surveyed 4 beach profiles at each of 8 sites between Ohawe and Kai Iwi, spanning a stretch of about 70 km of coast. The sites were selected as lying landward of potential offshore mining sites, away from rivers and headlands which may influence beach processes locally and where there was public access to the beach. After an initial survey in June 2011, the profiles were surveyed on a monthly basis from August 2011 to April 2012 using an R8 RTK GPS survey system. The 4 profiles surveyed at each site spanned a swath of beach about 400 to 700 m wide and were selected to provide a representative sample of beach processes along that part of the shore. The profiles were surveyed in late September 2011 following a storm event. There were 352 profiles surveyed in total over the 11 month period. Although the beach profile record is short, the South Taranaki Bight experienced a wide range of wave conditions over the 11-month survey period, including sizeable storm events (described in section 4).

The coast between Ohawe and Wanganui lies on the southern flank of the Cape Egmont 'mega-headland' and on a very exposed and energetic coast. It has seen continual tectonic uplift and erosion over the Holocene, producing almost continuous near-vertical, 30 – 50 m tall cliffs along about 70% of this coast. As the cliffs have retreated they have left behind a hard shore platform on which sandy beaches have developed at the base of the cliffs. The beaches tend to form in places where shallow re-entrants in the coast and headlands provide shelter from waves. Along a section of coast without cliffs that runs from the Patea River to about Waiinu, the beaches are backed by foredunes, landward of which transgressive dunes, now stabilised by farm pasture, have formed where sand picked-up from the beach by strong winds is blown far inland to smother low lying topography and rising ground.

In the north at Ohawe and Hawera, the beach sediments are overall coarser than those to the south, being largely poorly sorted gravelly medium to coarse sands and fine gravels, with much of the coarser material appearing to derive from cliff collapse. In the south the beaches are sandier being primarily moderately sorted gravelly medium sands. In the north at Ohawe and Hawera the beaches also tend to be narrower and steeper (ranging 4 – 7 degrees) than the beaches to the south where the beach slope of the order of 2 – 4 degrees which is a reflection of the differences in grain size of the sediment (coarse sediment builds steeper beaches).

The historical record of rates of cliff line retreat is sparse, patchy and discontinuous for this coast. For instance, in the Inaha to Patea coastal section, one study in 1978 of all historic information (field measurements, maps, aerial photographs from the late 1800s to mid-1970s) points to erosion of the cliff line, with erosion rates ranging from 0.05 m/yr to 1.1 m/yr. Erosion was recorded at Ohawe (0.63 m/year) and at two sites in Manawapou (0.64 m/year and 0.67 m/year). Another study in 1996, which used a map from 1871 and aerial photos from 1951, 1972, 1984 and 1993 as well as field measurements in 1996, reported long-term cliff retreat as 0.48 m/year (1871 – 1996), but the rate of retreat varied between 0.03 m/year (1951 – 1984) and 0.35 m/year (1984 – 1996). Apart from a report of cliffs near Waipipi (near Waverley) eroding at 0.35 m/year made by comparing surveys from 1906 to 2005, there are no measurements of historical rates of erosion or accretion on the shore between Patea and Waitotara/Waiinu. Active erosion of the cliffs is expected, as they are composed of soft sedimentary material, largely Pliocene Wanganui Series mudstones, sandstones, shellbeds, limestone and conglomerates. In places this is capped with Pleistocene conglomerates, marine sand, dune sand, volcanic sand and lignite bands. The cliff face erodes catastrophically by slumping, also aided by groundwater seepage through the strata and joints in the cliffs, large waves undercutting the base and removing slumped material and perhaps tectonic activity such as earthquakes. The overall picture is one of active erosion all along the cliffed shore.

Cliff erosion supplies sediment to the beaches, although the actual rate of breakdown of cliff material deposited as slumps on the beach and the total supply of sandy and gravelly material to the beaches from cliff erosion is unknown. Sand and gravel delivery to the coast also comes from the rivers including: Waingongoro (8,357 t/yr), Tangahoe (34,192 t/yr), Manawapou (14,289 t/y), Patea (201,570 t/yr) and Waitotara (128,754 t/yr).

Sand is also transported into and through the area from alongshore and primarily by waves. Transport can be particularly large at times of storms when large waves create a surf zone and corridor for sand transport more than 500 m wide. Under these conditions sand is moved in pulses or slugs along the shore, which are visible in the beach profile records. Sand moving in this wide corridor can bypass small headlands and promontories and ‘jump’ from beach to beach as it is driven along the shore. Sand is also stripped from the beaches via rip channels and temporarily stored in bars and banks in the nearshore. These bars and banks cause the waves to beak offshore, dissipating energy and thus serve to protect the beach from erosion. In quieter periods of long low swell, sand is returned by wave generated currents from the seabed to the shore where it’s seen coming ashore as swash bars on the lower to mid-beach. Wave energy in the South Taranaki Bight comes primarily from large southwest swells from the Southern Ocean and also locally generated wind waves from the Tasman Sea that vary in size and direction with season. Numerical modelling used to provide a 20 year hindcast of wave conditions for the South Taranaki Bight, showed that the largest wave heights are found off the western end of the Taranaki Peninsula, decreasing further south with increasing shelter from prevailing SW swell. This causes a relatively strong energy transfer, principally from the WSW, at the northern end of the South Taranaki Bight, while further south, the more southerly energy components become blocked. Because of the curvature of the shoreline the wave energy reaching the coast is at an oblique angle (i.e., not perpendicular to the coast) and drives sand transport from the NW to the SE along the shore. There is no local information on rates of sand transport along the shore.

An important characteristic of the South Taranaki Bight coast is the lack of accommodation space for sand. In order for sand to be deposited and stored on a beach, there has to be space available for it to accumulate in. On the South Taranaki Bight coast there are few bays, estuaries, large coastal re-entrants or headlands, where sand can accumulate and be stored out of the reach of waves. Accommodation space is limited by the tall cliffs. As a consequence sand accumulates in small shallow coastal re-entrants, such as where streams and rivers emerge on the shore, as small narrow (about 100 m wide) beaches at the foot of the seacliffs. The beaches are made up of a thin veneer of sand, possibly only metres thick over the rocky shore platform left by the retreating cliff line. A rocky shore platform is sometimes exposed at low tide at the base of the beach. As our beach profile data show, the sand in these beaches is very mobile and moves on and off the beaches according to wave conditions. While limited accommodation space sometimes permits incipient (small, unvegetated) dunes to form in the re-entrant at the stream mouths, there is no space for sand dunes to be accommodated at the base of the cliffs. As a consequence, high tides, combined with storm surge and large waves, a feature of this coast, reach right up to the cliffs and the entire beach is subjected to erosion, enhanced by backwash from the cliffs. Erosion is further enhanced by ground water and surface water flow originating in the cliffs and flowing though the beach where it emerges as seepage lines and springs at mid to low tide level. (Wet beaches erode more easily than dry beaches because of their high water content).

Changes in sand volumes measured at the eight beach survey sites between Ohawe and Kai Iwi over the period June 2011 to April 2012 show that the net change in beach volume varies greatly, and from erosion at some sites to accretion at others. There is no pattern of change in erosion and accretion along the shore. The total changes in sand storage over the period June 2011 to April 2012 were of the order of at least 6-times to 39-times greater than the net change in the volume of sand stored on the beaches.

Site	Length of beach spanned by profiles	Net change in beach volume (m^3/km of shoreline)	Total amount of sand moving on and off the beach (m^3/km of shoreline)
Ohawe	500	+23,200	137,000
Hawera	530	-7,300	67,000
Manawapou	680	+25,700	247,000
Patea	360	-15,900	169,500
Waverley	400	+4,700	109,600
Waiinu	400	-10,100	100,500
Ototoka	630	-6,100	205,100
Kai Iwi	420	-5,300	203,300

While Taranaki Regional Council reports erosion occurs mainly during the winter (May – August) and some autumn and spring storms also contributing to erosion, this was not evidenced in our beach profile data. However, it is consistent with the monthly mean values of significant wave height and wave energy flux showing a seasonal cycle with mean wave heights reaching a maximum in late winter and a minimum in late summer. Not unexpectedly, our beach profile data showed considerable variation in sand movement and storage between the eight sites surveyed. This is consistent with the knowledge that South Taranaki Bight beaches erode and accrete differently under similar storm conditions, and over just a few kilometres, due to local factors, including the geology of the coast, coastal orientation, sediment supply from rivers and interactions between headlands, offshore bars, currents, waves and the angle the waves arrive at the shore. The latter is affected by the offshore bathymetry which is quite complex and in the nearshore wave angle and breaking are further affected by shore platform and rock reef which induce wave breaking.

The overall picture we see for the South Taranaki Bight, is one of large variability in beach morphology between the sites surveyed, erosion and accretion throughout the year, small net storage of sand on the beaches and large quantities of sand moving on and off and along the beaches and being exchanged within the beach systems. With the exception of the sand stored in the transgressive dunes, the sand storage on beaches is rather transient in a system of highly connected sand storage units.

Information relating to TTR’s additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

1 Introduction

Trans-Tasman Resources Ltd (TTR) has secured permits and is prospecting for offshore iron sands along the West Coast, North Island. The areas of interest lie within the 12 nautical mile (nm) territorial sea along the North Taranaki Bight (NTB) and South Taranaki Bight (STB) (PP 50 383) and beyond the 12 nm boundary (PP 50 753) (Fig. 1–1). NIWA is undertaking a range of biogeophysical studies in the South Taranaki Bight for TTR to meet the likely requirements of consenting procedures to mine the seabed under the RMA and CSA.

At the time of writing this report (September 2012) the plan was for mining to involve dredging large depressions in the seabed, concentrating iron ore on board vessels and then returning the de-ored sand (tailings) to the seabed, where it will partially fill the depressions and also form mounds. Mining sites and areas where de-ored sand might be deposited are about 15 to 35 km offshore from Patea (Fig. 1–1). Depressions and mounds on the seabed have the potential to alter the direction of wave approach and wave height at the shoreline and therefore longshore transport and patterns of erosion and accretion at the shoreline, depending on the scale of the operations.

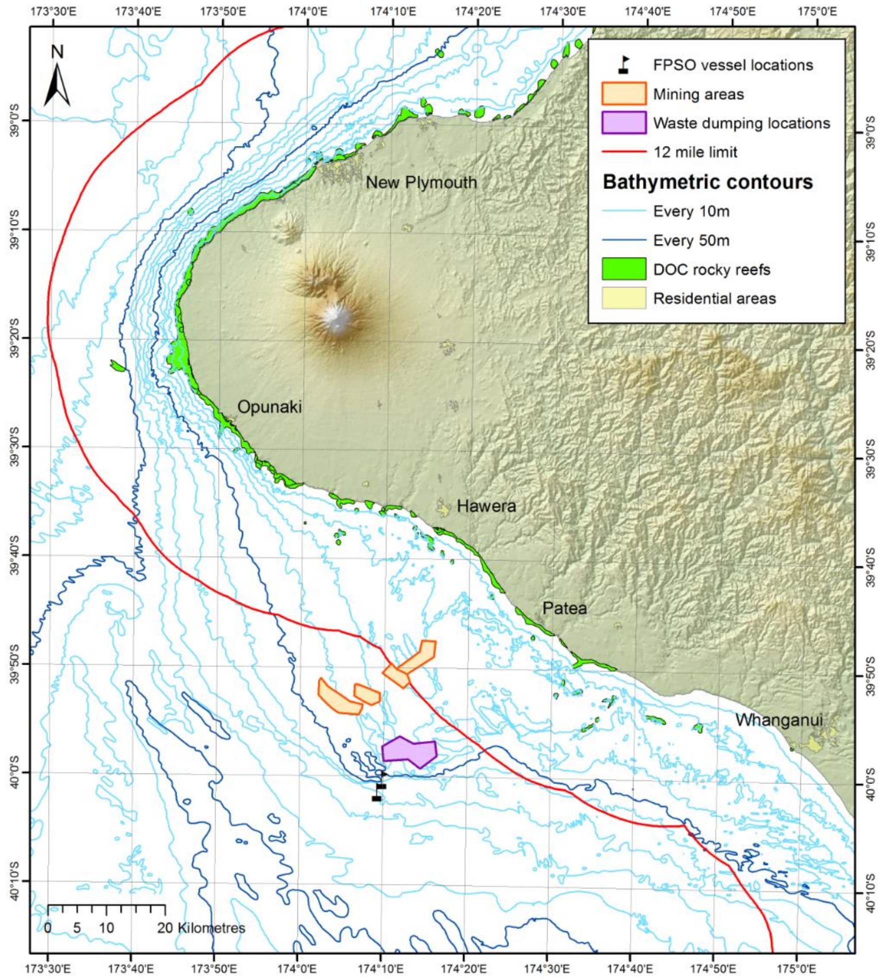


Figure 1-1: Mining sites and areas where de-ored sand (tailings) might be deposited on the seabed.

This report (Phase 1 studies) provides an assessment of the stability of the shoreline of the South Taranaki Bight extending 130 km from about Opunake to Wanganui. It reviews the historical and present day rates of change in the position of the shoreline and temporal variations in sand storage on the beaches. This information, along with planned investigations of cross shore sediment exchange and longshore flux and sand transport in the proposed mining area (Phase 2 studies), will provide a context and scale against which to gauge the potential effects of the sand mining of the offshore seabed.

2 Methods and sources of information

The assessment is based on a synthesis of information from: 1) a report on historical changes in shoreline position (MacDiarmid et al. 2010), 2) an 11 month record of beach profiles surveyed by NIWA for TTR to monitor the stability of the shoreline at eight locations between Manaia and Wanganui and inform any future monitoring programme required as part of consent conditions and 3) other available information and theory of the regional geomorphology and coastal processes.

2.1 Historical changes in shoreline position

The term historical shoreline change is used to describe changes in shoreline position that have taken place over timescales of decades. The shoreline in the South Taranaki Bight contains sections of tall near-vertical cliffs which are fronted by small beaches in places and sections of beach backed by sand dunes. Shoreline as used in this report refers to either the toe of the cliffs or the mean high water spring (MHWS) tide level which is often estimated as the seaward boundary of vegetation when survey marks are not available.

The information reported here is summarised from a review of shoreline change for the New Plymouth (NTB) to Waikawa (STB) coast (Fig. 2–1) in Chapter 3 of the Phase 1 Baseline Environmental Study of the South Taranaki Bight undertaken by NIWA (MacDiarmid et al. 2010). The full report collated information relating to wave and tidal climate, shoreline stability, ocean primary productivity, zooplankton communities, benthic macrofauna and macroflora, modelled reef fish distributions and abundance, modelled demersal fish distribution and abundance, whales and dolphin sightings, seabird occurrence, and the spatial distribution and intensity of commercial fisheries.

MacDiarmid et al. (2010), identified areas of erosion and accretion from an existing data base of variable source and quality including Regional and District Council reports, consultancy reports, peer reviewed papers and University theses. These studies used geomorphic evidence, old surveys and maps (some dating back to the late 1800's), charts and aerial photographs to estimate rates of erosion or accretion. The review determined that the data was sparse, patchy and discontinuous in time and space along the shore, but nevertheless provided a general overall picture of historical changes along the shoreline and a map of where the shore was eroding, accreting and stable. For the purpose of their mapping, MacDiarmid et al. (2010) divided the coast into eight sections on the basis of shoreline geology and coastal type (Fig. 2–1). More detailed information is available in MacDiarmid et al. (2010).

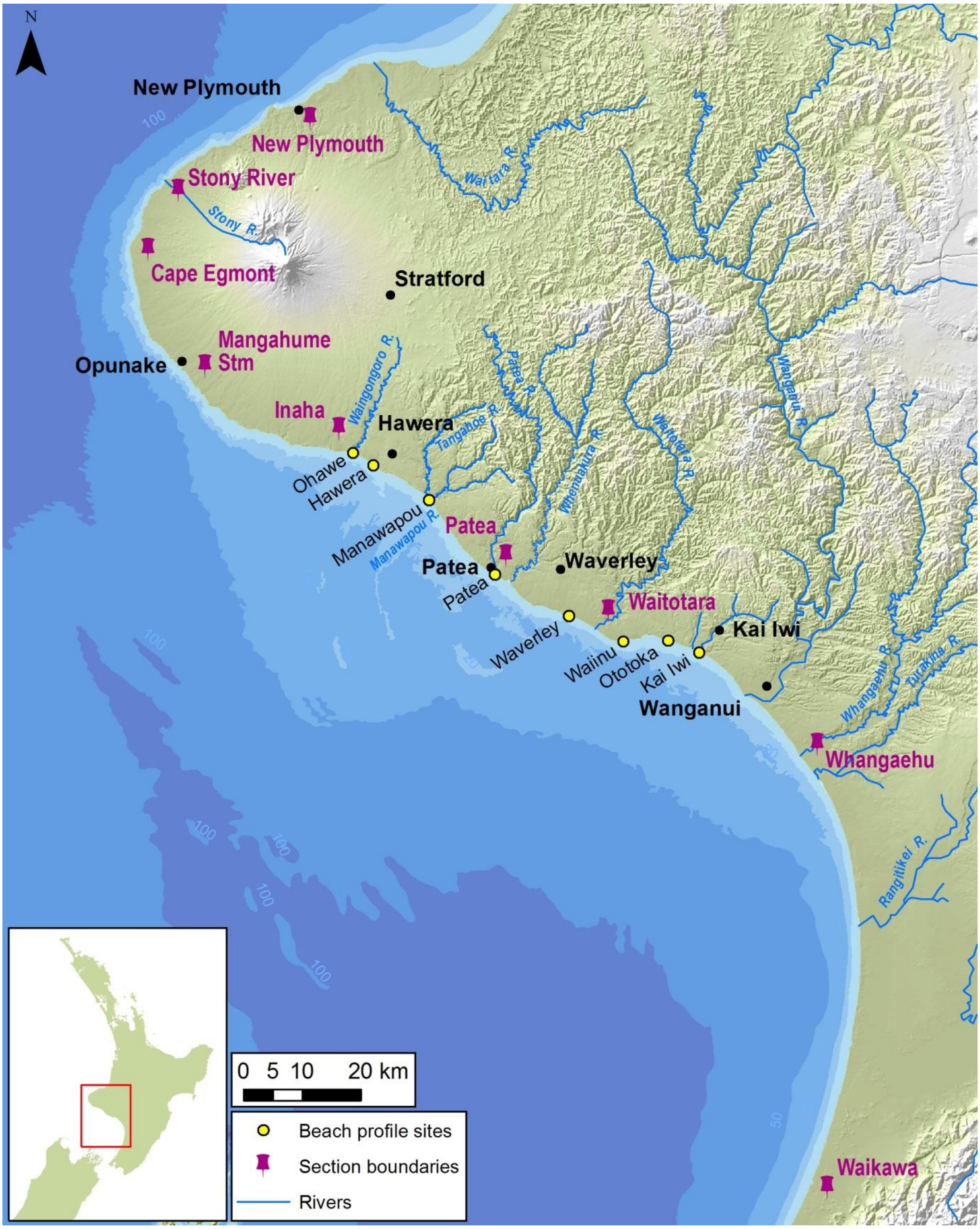


Figure 2-1: Area referred to in this study.

This report provides a description of the coastal geomorphology and rates of erosion and accretion for four of those sections that extend along the 140 km of coast, between Mangahume Stream and Whangaehu that are relevant to the offshore sand mining plans (Fig. 2–1). A map is presented in this report, showing historical shoreline change and areas of accretion, erosion, stability and variable change using data from MacDiarmid et al. (2010).

Stable shorelines were defined as those where the net erosion rate is less than 0.02 m/year over approximately the last one hundred years, and variable shorelines as where there are very small amounts of accretion and erosion but no trend in either direction over the period of record (TRC 2009).

2.2 Beach profiles

NIWA surveyed beach profiles at 8 sites between Ohawe and Kai Iwi, spanning a stretch of about 70 km of coast (Fig. 2–2) over an 11-month period. Prior to this study there was no beach profile information available for this section of coast.

Figure 2-2: Locations where beach profiles were surveyed along the South Taranaki Bight.

A beach profile is a surveyed shore-normal line that runs down the beach, typically between the foredune and the safe wading limit at low tide. Comparison of repeat surveys (if repeated often enough) shows how the beach and dune face build up and cut down (and sand storage changes) as sand moves on and off the beach in response to waves and wind, how the shoreline moves in and out, the amount of sand moving on and off the beach, and the frequency of those sand exchanges. Profile data is a record of the temporal variations in sand storage on the above high water and intertidal beach only, and not a measurement of cross-shore sediment exchange or alongshore flux in the surf zone. Beach profile measurements consider the site-specific response to local marine conditions and the sedimentary environment. The profile record from the South Taranaki Bight provides us with a picture of short-term changes at the time scale of months and storm events.

The beach profile sites were selected as lying landward of potential offshore mining sites, away from rivers and headlands which may influence beach processes locally and where there was public access to the beach. Four profiles were selected and surveyed at each site, spanning a swath of beach about 400 – 700 m wide. Our initial reconnaissance and visual observations made on subsequent trips to the sites over the 11 months of surveys confirmed the profile sites selected provided a representative sample of beach processes along that part of the shore. Although the beach profile record is short, the South Taranaki Bight experienced a wide range of wave conditions over the 11-month survey period, including sizeable storm events (described in section 4).

After an initial survey in June 2011, the profiles were surveyed on a monthly basis from August 2011 to April 2012 using an R8 RTK GPS survey system. The profiles were surveyed in late September 2011 following a storm event. There were 352 profiles surveyed in total over the 11 month period. A detailed description of the beach profile locations, surveying methodology and results is described in MacDonald et al. (2012).

The surveys were accompanied by photographs of the beach taken at the profile sites and field notes, to provide a record of changes in the beach characteristics and to aid in the interpretation of the survey data.

Pits were dug into each beach during one round of surveys to examine the stratigraphy of the sediment making up the beach (Fig. 2–3). The stratigraphy (the layers of different minerals and coarse and fine material) provides a record of the variability and sorting of beach sediment during erosional and depositional phases. Images of the stratigraphy are shown in section 4 of this report.

Figure 2-3: Pit dug in beach to examine sediment stratigraphy.

Surface sediments were collected from the mid-beach level on one occasion at all four profile sections at each of the eight sites. They were collected by scraping off the top 2-3 cm of sediment from the beach face. The samples were analysed by sieving and analysed for particle size distribution using GRADISTAT version 8.0 (Blott et al. 2010), which provides various granulometric statistics and a textural description for the sediment. Details are given in MacDonald et al. (2012).

The profile data was edited and analysed using NIWA's beach profile analysis toolbox (BPAT) which provides graphs of profile shape and statistics of shoreline movement and sediment volume changes. The data was edited to remove large rocks from the profiles so that the data would reflect changes in the volume of unconsolidated beach sediment (i.e., mostly sand and gravel).

The BPAT 'spaghetti' plots of profiles (e.g., Fig. 2–4) show the actual survey profiles and how the elevation (m above a datum, where 0 = Taranaki MSL) of the beach changes with distance (m from a start point) between the dune/high tide and low tide levels. Comparing the lines of two individual surveys shows the changes in elevation in the beach the two surveys and also the excursion (the amount of horizontal back and forth movement) of the beach face. The plot of all the profiles together displays the range of fluctuation over the entire survey record. The plots also show beach berms[1] building on the upper beach above high water and swash bars[2] on the lower beach. Swash bars typically signify shoreward migrating pulses of sand.

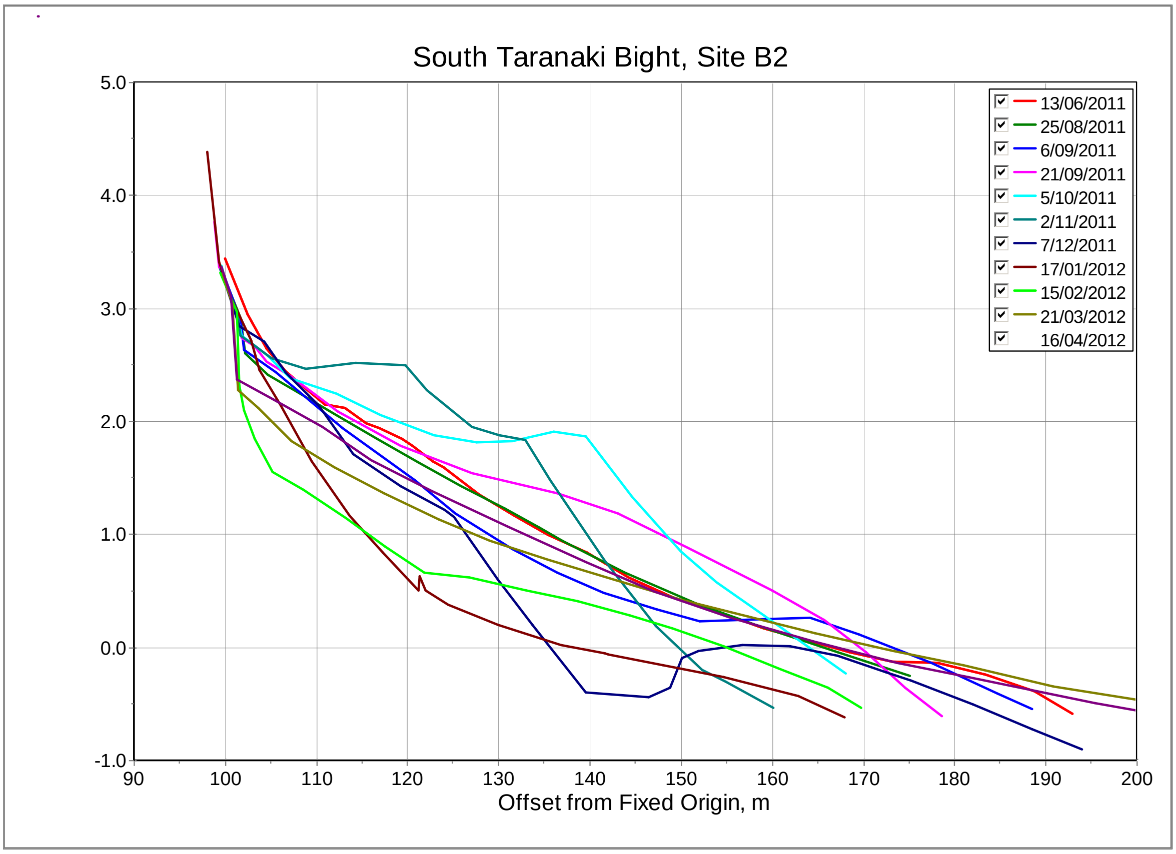


Figure 2-4: BPAT spaghetti plot of beach profiles showing 11 surveys. The elevation is in metres above a datum, where 0 m = Taranaki Mean Sea Level.

[1] Nearly horizontal plateaus on the beach face or backshore, formed by the deposition of sand by wave action.
[2] Low broad sandy bars formed by sediment in the surf and swash zones, separated by linear depressions, or runnels, running parallel to the shore.

The BPAT beach volume (cut/fill) plots (e.g., Fig. 2–5) show how the volume of sand (m^3/m of beach length) stored in the beach (above a reference elevation or datum) changes over time, and also phases of erosion (cut-down) and accretion (build-up).

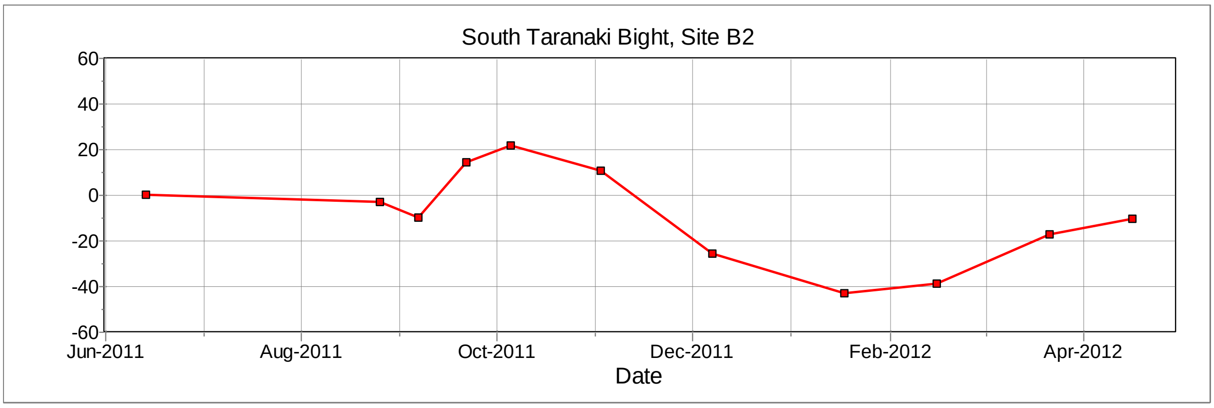


Figure 2-5: BPAT beach volume plot showing changes in volume of sand stored on the beach as calculated from 11 beach profile surveys.

The BPAT 'box-and-whisker' excursion distance plots (e.g., Fig. 2–6) show the amount of horizontal back and forth movement of the beach face at selected heights above a datum. The example below shows a very small amount of back and forth movement of the beach face on the upper beach (at 3 m elevation) and more back and forth movement (about 32 m) on the mid-beach (at 1.0 m elevation). The left and right hand end of the box represent the 25th and 75th percentile. The ends of the whiskers represent the minimum and maximum of the data. Any data not included between the whiskers are plotted as an outlier with a dot or star. The red line defines the mean profile shape.

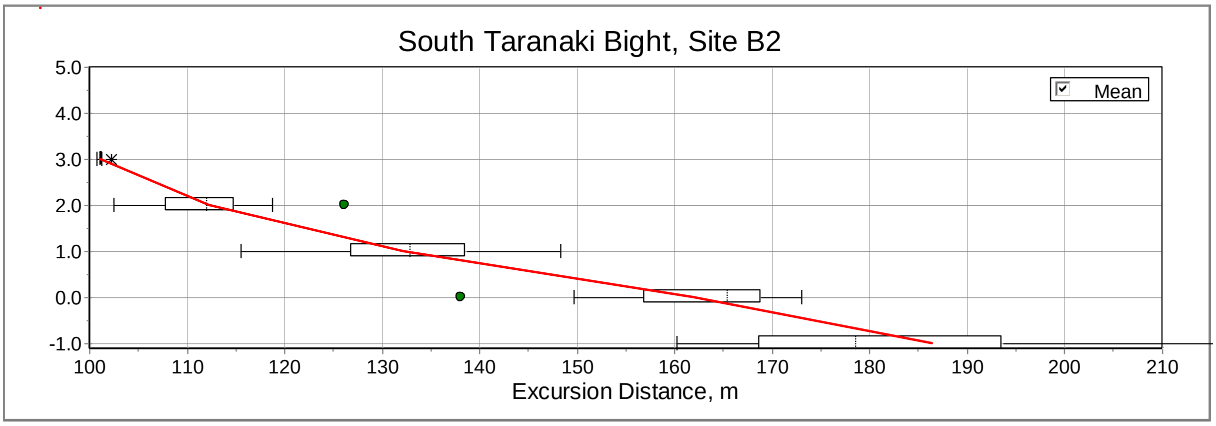


Figure 2-6: BPAT excursion distance plot showing the amount of back and forth movement of the beach face at 0.5 m intervals above a datum.

BPAT also tabulates the survey data and statistics from which the graphs are derived. These tables and graphs are the source of the data in Appendix B.

3 Historical changes in shoreline position

This section describes historical changes in shoreline position and rates of erosion and accretion (m/year) for four sections of the coast, namely Mangahume to Inaha, Inaha to Patea, Patea to Waitotara and Waitotara to Whangaehu.

Major coastal landform types and foreshore sediment types are summarised in Figure 3–1. In the north and south to about Inaha the foreshore is largely mixed sand and gravel with cobbles and boulders on parts of the shore. To the south of Patea sandy foreshore predominates. Along much of the coast there is an actively eroding, 30 – 40 m tall, near-vertical seacliff towering over the beach. Sandy foreshore backed by foredunes, with transgressive dunes extending inland over rising ground, characterise the coast between Patea and Waitotara. To the south of Wanganui the foreshore is largely sandy beach backed by dunes extending inland over rising ground.

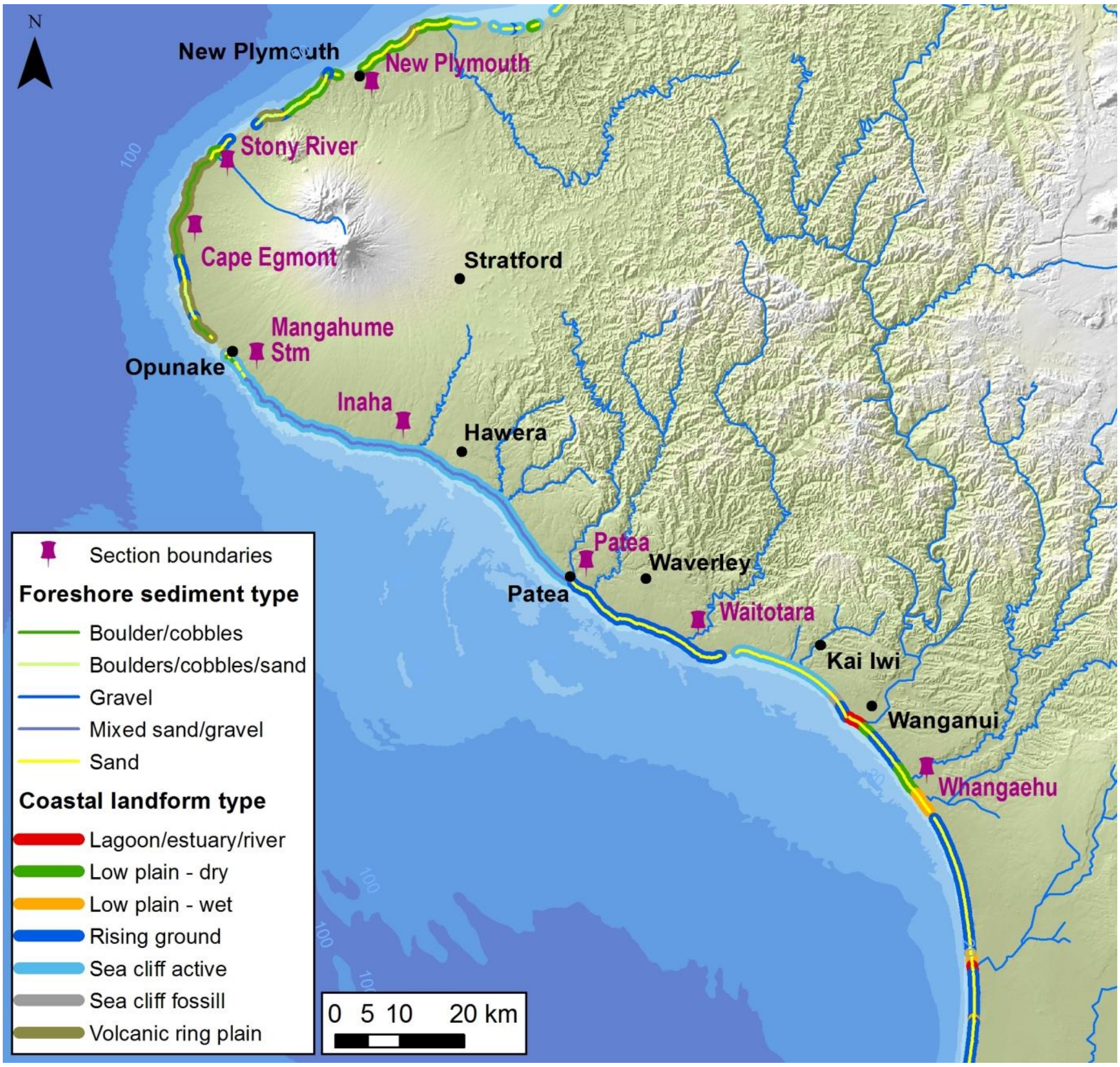


Figure 3-1: Major coastal landform types & foreshore sediment types (source: Coastal Explorer, NIWA website).

3.1 Shoreline change - Mangahume Stream to Inaha Stream

This is the southern section of the hard, volcanic lahar coast around Mount Taranaki. The shoreline is mostly hard cliffs cut by numerous ring plain rivers and streams and a few sand dunes near Kaupokonui Stream (TRC 2009 report). There is limited access to this section of coast, generally through private land. Measurements by Gibb (1978) show a stable coast at Punehu, Pihama and Glen Road and erosion at Normanby Road (-0.16 m/year), Winks Trig (-0.34 m/year) and Raine Road (-1.11 m/year). TRC (2009) reported a general estimate of cliff regression of -0.1 m/year, based on work for Kupe by Maunsell Ltd in 2004, although the geographic location of the measurement site is unknown. There was historical sand extraction of 36,600 m3 of gravel between 1945 and 1960 from Raine Road (near Ohawe) (TRC 2009).

3.2 Shoreline change - Inaha Stream to Patea River

This section includes beach profile sites Ohawe, Hawera, and Manawapou.

There has been continual tectonic uplift in this area (McGlone et al. 1984). The shoreline is almost continuous 30 – 40m tall, soft sedimentary cliffs comprised of largely Pliocene Wanganui Series mudstones, siltstones, sandstones, shellbeds, limestone and conglomerates. In places this is capped with Pleistocene conglomerates, marine sand, dune sand, volcanic sand and lignite bands. The cliffs are fronted by steep sand or gravelly beaches, and some offshore papa reefs. The coastal section is incised by three rivers, the Waingongoro, Tangahoe and Manawapou.

Erosion of the soft sedimentary cliffs (compounded by groundwater seepage) is evident (TRC 2009), and catastrophic failure and slumping can cut back the cliff line by 1 – 2 m at a time (pers com Kate Giles). Gibb (1978) found that all historic information (field measurements, maps, aerial photographs from the late 1800s to mid-1970s) points to erosion of the cliff line, with erosion rates ranging from 0.05 m/yr to 1.1 m/yr. Erosion was recorded at Ohawe (0.63 m/year) and at two sites in Manawapou (0.64 m/year and 0.67 m/year) (Gibb 1978). TRC (2009) reports on work by Single in 1996, which used a map from 1871 and aerial photos from 1951, 1972, 1984 and 1993 as well as field measurements in 1996. Long-term cliff retreat was calculated at 0.48 m/year (1871 – 1996), but the rate of retreat varied from 0.03 m/year (1951 – 1984) and 0.35 m/year (1984 – 1996). Erosion at Ohawe boat ramp car park between 1984 and 1996 was calculated at 0.58 m/year. There was gravel extraction from Manawapou in 1940 (14,000 m^3) and quarrying of sand and gravels from Ohawe beach prior to 1955 and during the 1960s (TRC 2009).

3.3 Shoreline change - Patea River to Waitotara River

This section includes beach profile sites Patea and Waverley.

The soft sedimentary cliffs are comprised of largely Pliocene Wanganui Series mudstones, sandstones, shellbeds, limestone and conglomerates. In places this is capped with Pleistocene conglomerates, marine sand, dune sand, volcanic sand and lignite bands. There has been constant tectonic uplift in this area (McGlone et al. 1984). The shoreline is dominated by sand beaches backed by dunes, and transgressive dunes that are now stabilised in farmland. There is a section of tall cliffs fronted by a small beach between Waipipi and Caves Beach. The shoreline around Patea River mouth is very dynamic due to the interaction of waves and river at the entrance. This interaction explains Gibb's 1978 reports of four sections of the Patea shoreline as stable (0 m/yr), eroding (0.85 m/yr) and accreting (0.99 and 2.05 m/yr). Patea Township has a history of flooding, sand advancing towards the town and erosion. There have been various modifications to the shoreline/river/estuary in response to these threats, including erosion prevention efforts around the gas pipeline that crosses the estuary (planting, rock wall and renourishment). Shoreline changes to the beach and dunes north of the town likely occurred due to modification of the river and estuary for navigation. Cliffs near Waipipi (near Waverley) were estimated to be eroding at 0.35 m/year by comparing surveys from 1906 to 2005 (TRC 2009). There was historic iron sand mining at Waipipi between 1971and 1989 (TRC 2009).

3.4 Shoreline change - Waitotara River to Whangaehu River

This section includes beach profile sites Waiinu, Ototoka and Kai Iwi.

In the north this section of shoreline consists of narrow sandy beaches backed by tall, near-vertical eroding sedimentary cliffs (Horizons Proposed One Plan 2007). The soft sedimentary cliffs are comprised of largely Pliocene Wanganui Series mudstones, sandstones, shellbeds, limestone and conglomerates. In places this is capped with Pleistocene conglomerates, marine sand, dune sand, volcanic sand and lignite bands. South of about Wanganui the shoreline comprises rising ground and low plains and beaches backed by dunes. The coast around Wanganui is tectonically active with uplift rates of about 0.25 mm/yr (Shand, 2001). TRC (2009) reported erosion at Mowhanau Beach of 0.35 – 0.7 m/year. Gibb (1978) reported erosion between 1940 and 1975 for Kaitoke (2.0 to 1.6 m/year), Wanganui (1.43 m/year) and South Wanganui (2.22 to 5.45 m/year). South Wanganui also had one report of accretion (4.5 m/year) which may be due to river sediment input. Reports by Gibb (1978) of accretion (3.33, 3.70, 9.09, 5.00 and 1.25 m/year) at several points along the beachside suburb of Castlecliff (just north of Wanganui River) may also be due to deposition of river sediments. Shand (2001) reported that jetties built at the mouth of the Wanganui River between 1884 and 1940 caused the shoreline to prograde by ~700 m near the entrance and up to 100 m north of the river, with up to 10 m of progradation from 1990 to 2000. This is in contrast to Shand’s measurement of a background regional erosional trend of 0.2 – 0.6 m/yr. Shand (2001) reported a great deal of sand bar movement within the nearshore (surf zone) in the Wanganui region, as a result of episodic high wave energy periods.

3.5 Overview of shoreline stability in the South Taranaki Bight in historical times

The stability of the shoreline in historical times is summarised in Figure 3–2 which shows areas of accretion, erosion, stable and variable change. The section of shoreline from Mangahume Stream to Inaha is largely erosional. Much of the shoreline, including the sections form Inaha to Patea and Waitotara to Wanganui, comprises 30 – 40m tall, near-vertical soft sedimentary cliffs that are actively eroding, mainly by slumping causing the cliff line to retreat at rates of 0.05 to 1.1 m/yr. Narrow sandy beaches fronting the cliffs provide little protection from wave action and erosion. There are no measurements of rates of erosion or accretion on the shore between Patea and Waitotara/Waiinu, perhaps because of limited road access to this section. South of Whangaehu there is a mixture of accreting shore and variable (erosion/accretion) shore. The only section of the shoreline classified as stable is for a beach near Oaonui north of the Mangahume Stream (Gibb 1978).

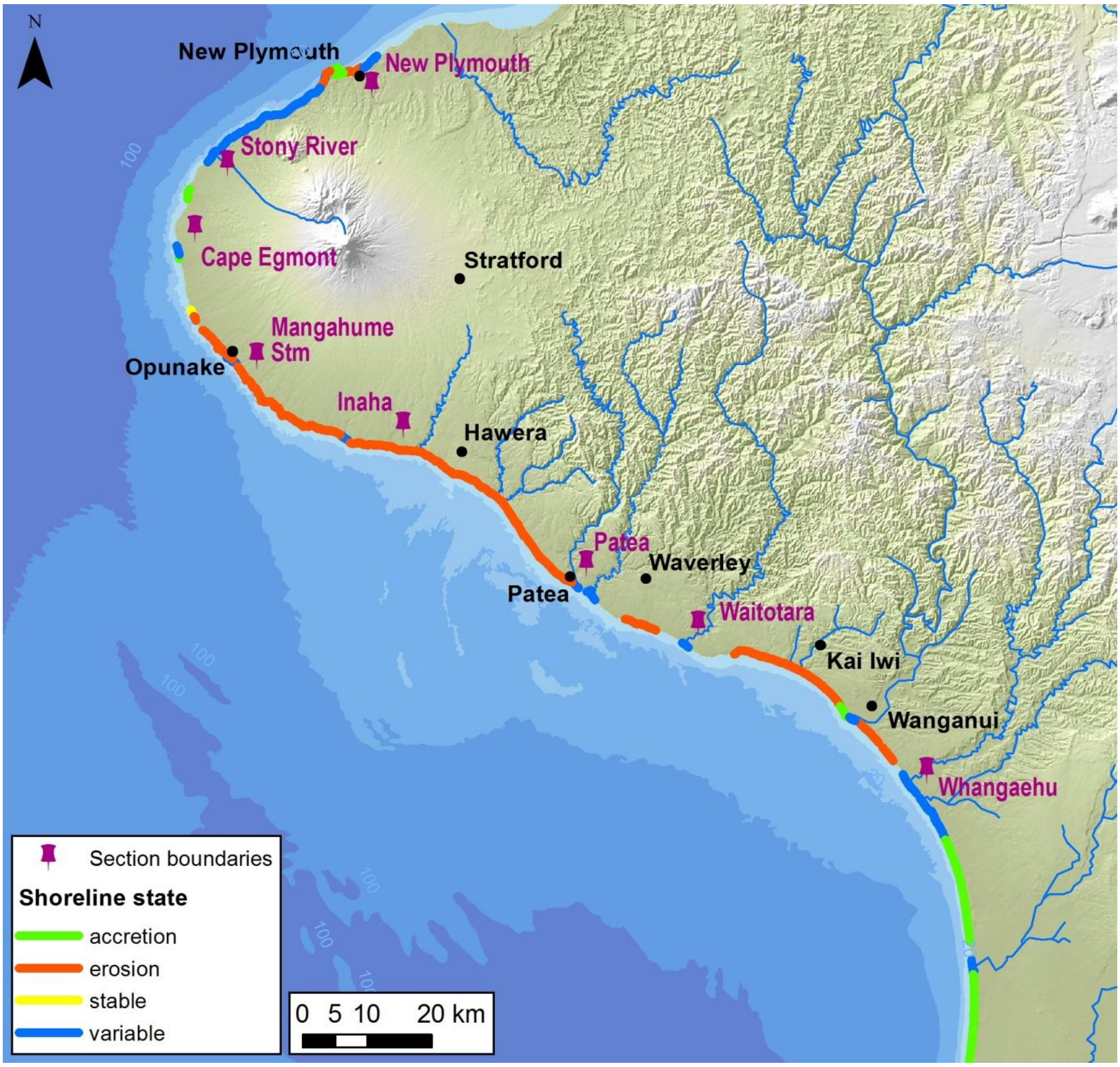


Figure 3-2: Shoreline stability in the South Taranaki Bight in historical times. Areas for which there are no data are left blank. (Map modified from MacDiarmid et al. 2010).

4 Short-term changes in shoreline position and sand movements

This section describes short-term changes in shoreline position and rates of erosion and accretion based on the 11 surveys of beach profiles by NIWA (Figure 4-1).

Figure 4-1: Locations where beach profiles were surveyed along the South Taranaki Bight.

Although the beach profile record is short, the South Taranaki Bight experienced a wide range of wave conditions over the 11-month long survey period, including sizeable storm events. NIWA had wave measuring instruments deployed in 10 – 12 m water depth at four locations along the South Taranaki Bight, for two approximately 8 week long periods during the time that profiles were measured. Figure 4-2 shows a time series of measured significant wave height (the average of the highest one-third of the waves in a record. The record shows that even in these short records there are 10 events where the significant wave height exceeded 2 m and for five of these events wave heights exceeded 2 m for more than two days. The vertical blue lines indicate the period of the 21 – 23 September 2011 post-storm beach profile surveys which captured a large event.

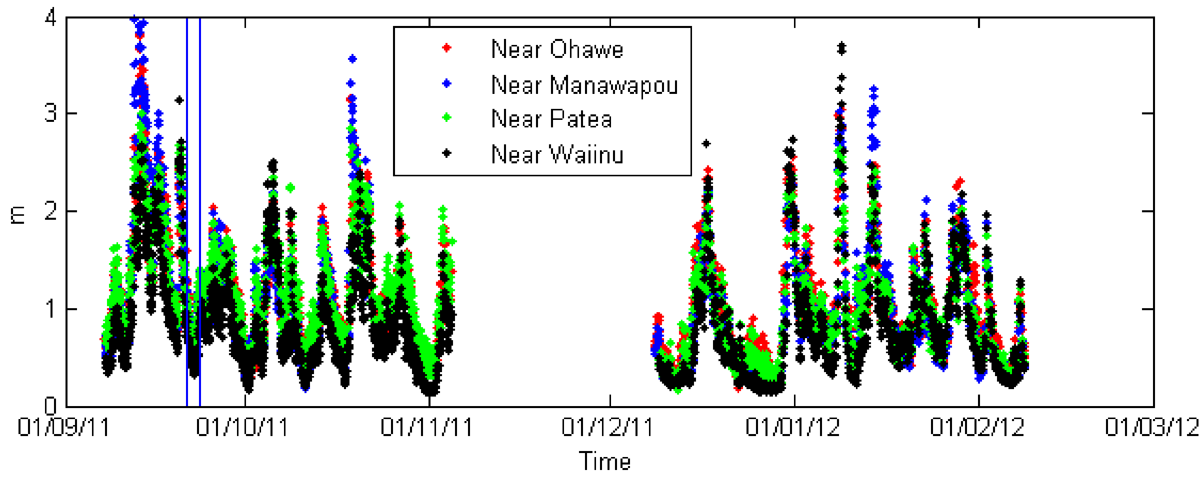


Figure 4-2: Time-series of significant wave height (m) for September 2011 to February 2012.

Thus the beach profile record should provide a good basis for a description of short-term changes in beach profile state.

A description of beach profile changes at each of the beach profile sites follows.

4.1 Ohawe

Ohawe Beach (site H) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 500 m of shoreline.

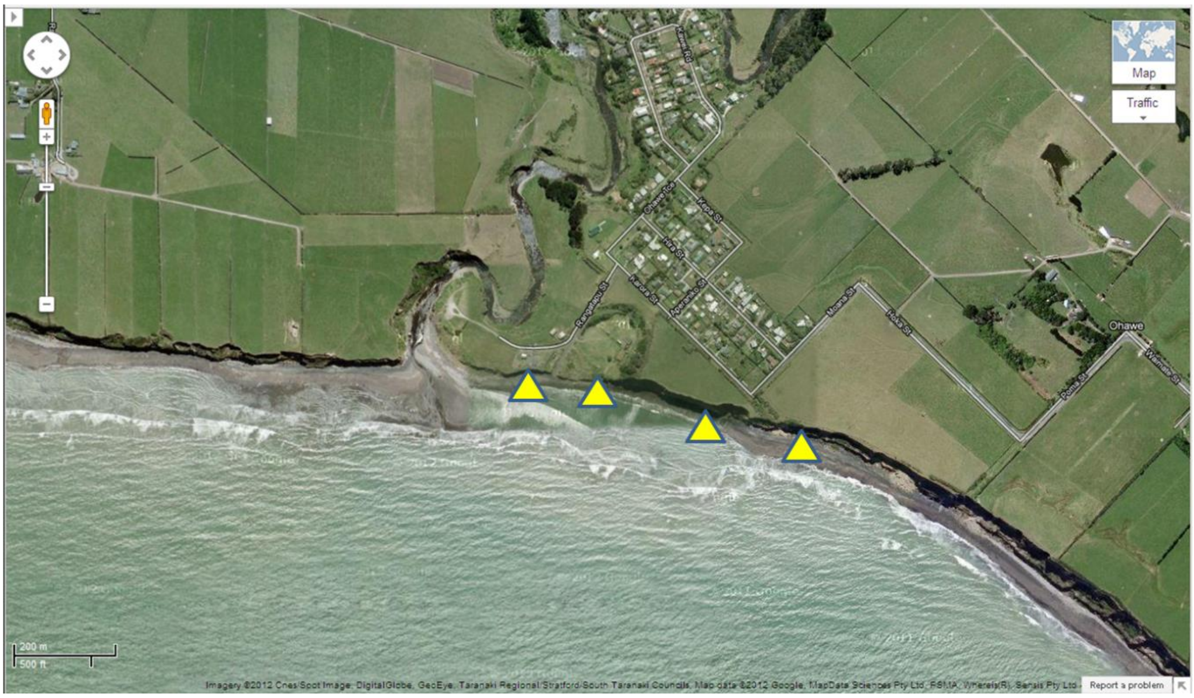


Figure 4-3: Ohawe Beach and profile sites (Google image).

Ohawe Beach is formed where a small stream cuts through coastal cliffs and emerges on the beach (Figure 4-3). Here, a largely sandy beach about 70 – 130 m wide fronts near-vertical 40 m tall and actively-eroding sea cliffs. Rockfalls and slumping from the cliff face provides boulders, cobbles, gravel and sand to the beach. Our field observations made during monthly profile surveys, suggest that the soft sedimentary sandstone and mudstone components of this material breaks down rapidly and that slumped deposits seen at the toe of the cliffs on one survey may have been partially washed away by waves on a subsequent visit. A rocky reef shore platform is exposed in places on the mid and lower beach (Figure 4-4, upper left and right panels). There is little accommodation space for beach sand which appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves reach right to the top of the beach and the toe of the cliffs which means there is no space for sand dunes to build out of the reach of waves and erosion. Ground water and surface water drains from cliffs and runs through the beach face to emerge near low tide level.

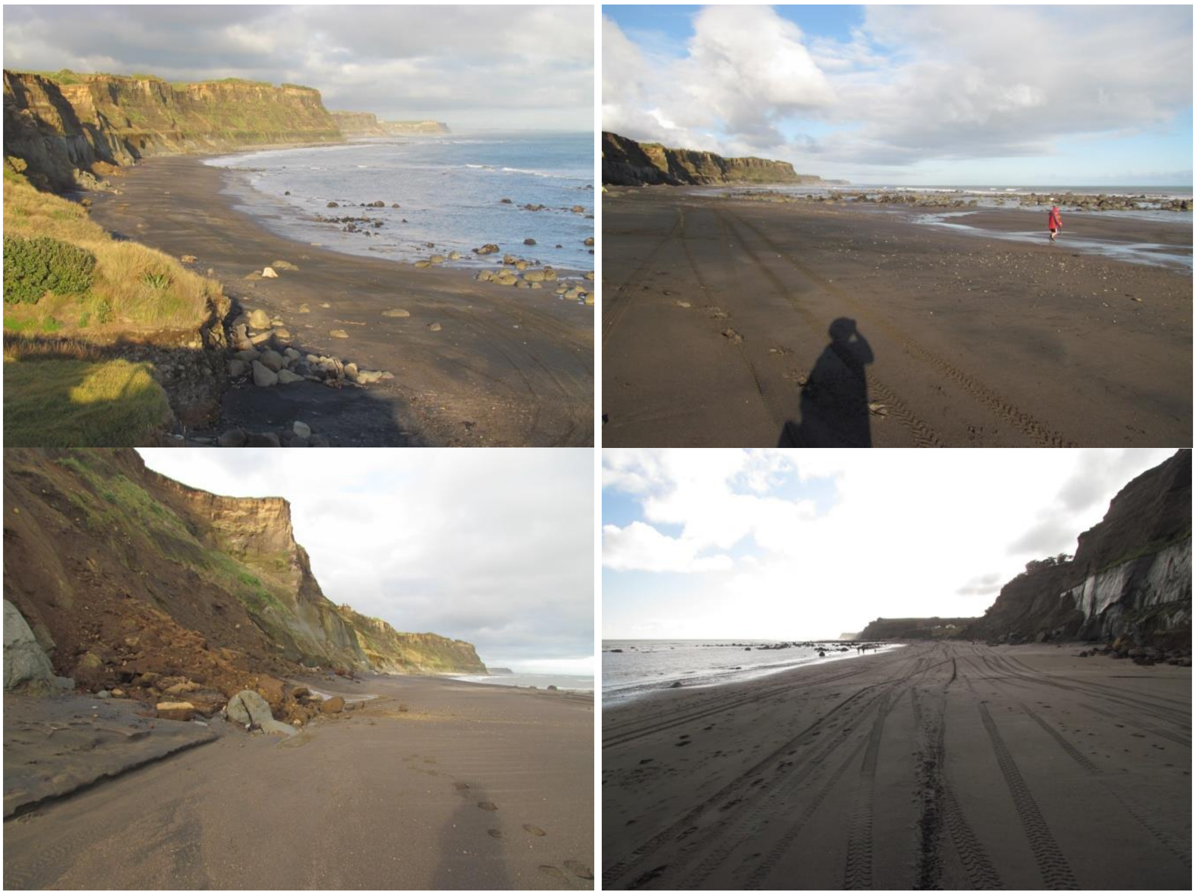


Figure 4-4: Views of Ohawe Beach.

Pits dug in the beach (Figure 4-5) show alternating layers of coarse and fine sediments made up of fine black sands and shelly pebbly sands and gravels, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between.

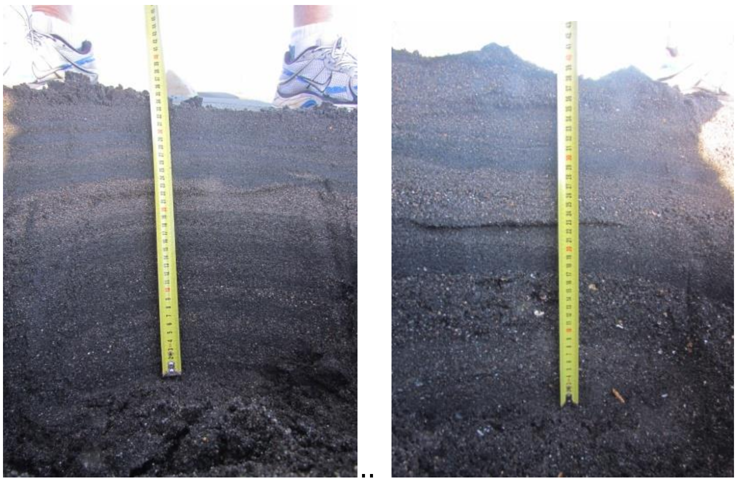


Figure 4-5: Pits dug in the beach showing alternating layers of fine and coarse material (scale in centimetres).

The grain size distribution of samples from the mid beach level is shown in the Table 4-1 below.

Table 4-1: Particle size of beach sediment from Ohawe. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Ohawe	1	Moderately sorted, slightly gravelly, medium Sand	1	99	<1	0.436
Ohawe	2	Poorly sorted, gravelly, medium Sand	6	94	<1	0.790
Ohawe	3	Poorly sorted, gravelly, medium Sand	16	84	<1	1.124
Ohawe	4	Moderately sorted, slightly gravelly, medium Sand	2	98	<1	0.512

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down by 0.8 to 1.4 m, and the beach face shows excursions back and forth of about 13 m, as sand comes and goes in response to wave events. The beach was most eroded in the June (profiles H1 – H3) and in the October – through January (profiles H1 – H4) and was most built up in August and March. A survey undertaken on 23 September following a storm resulted in a small amount of erosion on all 4 profiles. Active beach building is evidenced in the profile record by swash bars on the lower beach (waves of sand 0.6 m tall and 30 m long) coming ashore. Sand movement alongshore is evidenced by slugs of sediment in low, broad, shore-normal waves of sand (Fig. 4–3, lower right image). Over the 11 month record, the NW profile (H1) showed a net reduction in beach volume, while the SE profiles (H2, H3 and H4) showed a net increase. Overall there was a net gain in beach sand volume recorded in 11 months of 23.2 m^3/m of beach (or about 23,200 m^3/km of shoreline). However the minimum amount[3] of sand moving on and off the beach recorded in the 11 surveys was 6-times this at 137 m^3/m of beach (or about 137,000 m^3/km of shoreline).

[3] This is a minimum amount because additional surveys during the period would have recorded additional sand movements on and off the beach.

4.2 Hawera

Hawera Beach (site G) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 530 m of shoreline.

Figure 4-6: Hawera Beach and profile sites (Google image).

Hawera Beach is formed where a small stream cuts through coastal cliffs and emerges on the beach (Figure 4-6). Here a sandy and boulder and cobble strewn beach about 60 – 130 m wide fronts near-vertical 50 m tall and actively-eroding sea cliffs. Rockfalls and slumping from the cliff face provides boulders, cobbles, gravel and sand to the beach. This beach has the most boulders and cobbles of the 8 sites where beach profiles were surveyed. A rocky reef shore platform is exposed in places in the lower beach and is submerged in the nearshore. There is little accommodation space for beach sand which appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves reach right to the top of the beach and the toe of the cliffs which means there is no space for sand dunes to build out of the reach of waves. Ground water and surface water drains from cliffs and seeps into the upper beach, then runs through the beach to emerge near low tide level (top left image in Figure 4-7 below).

Figure 4-7: Views of Hawera Beach.

Pits dug in the beach (Figure 4-8) show alternating layers of coarse and fine sediments made up of fine black sands and shelly pebbly sands and gravels, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between.

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Figure 4-8: Pits dug in the beach showing alternating layers of fine and coarse material (scale in centimetres).

The grain size distribution of samples from the mid beach level is shown in Table 4-2 below.

Table 4-2: Particle size of beach sediment from Hawera. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Hawera	1	Poorly sorted, gravelly, coarse Sand	21	79	<1	1.198
Hawera	2	Poorly sorted, gravelly, coarse Sand	28	72	<1	1.395
Hawera	3	Poorly sorted, gravelly, medium Sand	30	70	<1	1.443
Hawera	4	Poorly sorted, sandy, fine Gravel	66	34	<1	1.781

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down by 0.4 to 1.2 m, and the beach face shows excursions back and forth of about 8 m, as sand comes and goes in response to wave events. Beach erosion and accretion shows a similar pattern at profiles G2 and G3. Profile G1 was well built up in March and April whereas profiles G2 – G4 were degraded. A survey undertaken on 23 September following a storm event showed erosion on profile G1 and accretion on profiles G2, G3 and G4. Over the 11 month record profile G1 showed net accretion while profiles G2 – G4 showed net erosion. An accretionary pulse (beach build-up) occurred in December on profiles G4 and G3 (in the NW), in December to February on profile G2 and in March on profile G1 (in SE). This data and observations on the beach made during our surveys are interpreted to mean that slugs of sediment migrate NW to SE along the shore resulting in sand build-up and beach build-out in some places, and retreat in others. Beach build-up was evidenced in the profile record by swash bars (0.3 m tall and 50 m long) coming ashore. Overall there was a net loss in beach sand volume of 7.3 m^3/m (or about 7,300 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in 11 months was 9-times this at 67.1 m^3/m of beach (or about 67,000 m^3/km of shoreline).

4.3 Manawapou

Manawapou Beach (site F) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 680 m of shoreline with 2 profiles situated either side of the Manawapou River.

Figure 4-9: Manawapou Beach and profile sites (Google image).

Manawapou Beach is formed where the Manawapou River cuts through coastal cliffs and emerges on the beach (Figure 4-9). Here, a largely sandy beach about 70 – 100 m wide fronts near-vertical 40 m tall and actively-eroding sea cliffs. Rockfalls and slumping from the cliff face provides boulders, cobbles, gravel and sand to the largely sandy beach. A rocky reef shore platform is exposed in places on the lower beach to the NW. Swash bars on the mid and lower beach are evidence of sand coming ashore (Figure 4-10, lower two images). The Manawapou River and the Tangahoe River (about 600 m along the coast to the NW) (Fig. 4–8), provide sediment to the beach and also affect beach processes by eroding the beach through direct scour and by maintaining a high water table in the beach in the vicinity of the river mouths. Beach sand build up at the Manawapou River mouth was never observed to be sufficient to build a bar and temporarily close off the river mouth at low flows. There is little accommodation space for beach sand to accumulate at the base of the cliffs and the beach appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves reach right to the top of the beach and the toe of the cliffs which means there is no space for sand dunes to build out of the reach of waves. Ground water and surface water drains from the cliffs. It then runs through the beach face to emerge near low tide level and ponds behind the sand bars.

Figure 4-10: Views of Manawapou Beach and river mouth.

Pits dug in the beach (Figure 4-11) show alternating layers of coarse and fine sediments made up of fine black sands and shelly pebbly sands and gravels, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between. There are a considerable proportion of gravelly sands making up the beach.

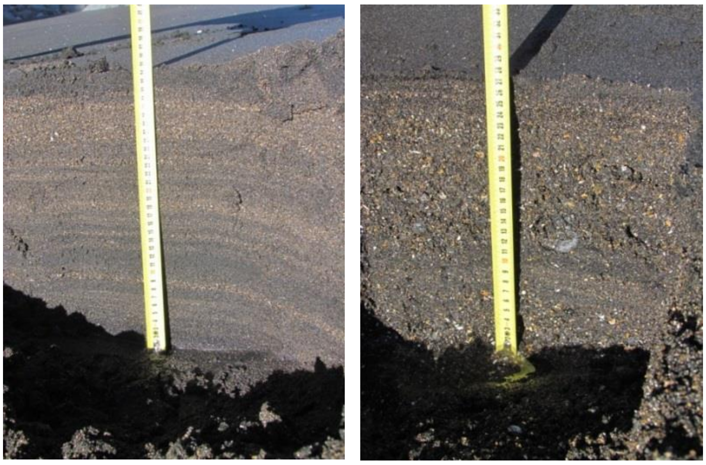

Figure 4-11: Pits dug in the beach showing alternating layers of fine and coarse material (scale in centimetres).

The grain size distribution of samples from the mid beach level is shown in Table 4-3 below.

Table 4-3: Particle size of beach sediment from Manawapou. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Manawapou	1	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.489
Manawapou	2	Moderately sorted, slightly gravelly, coarse Sand	2	98	<1	0.606
Manawapou	3	Moderately sorted, slightly gravelly, medium Sand	5	95	<1	0.692
Manawapou	4	Moderately sorted, slightly gravelly, medium Sand	4	96	<1	0.635

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 0.6 to 1.8 m, and the beach face shows excursions back and forth of about 12 m, as sand comes and goes in response to wave events. The profile located to the SE of the river mouth (F1) shows very large changes in beach volume compared to the other profiles. The three profiles located to the NW of the river mouth (F2, F3 and F4) show similar patterns of change to each other. All four profiles show little change through June – August. The build-up and cut-down of the beach takes place at different times on different profiles. A survey on 22 September following a storm showed erosion on profiles F2, F3 and F4 and a slight net build-up of sand on profile F1. Over the 11 month record, profiles F1, F2 and F4 showed a net increase in beach volume (with profile F1 showing substantial accretion), while profile F3 showed zero change. The difference in patterns of erosion and accretion between the profiles is interpreted to be caused by slugs of moving sediment along the shore resulting in sand build-up and beach face build-out in some places, and retreat in others. Flows from the rivers may also have had an effect on eroding the beach or providing sand to the littoral system. Beach build-up was evidenced in the profile record by swash bars (0.5 m high and 50 m long) coming ashore (Fig. 4–9). Overall there was a net gain in beach sand volume of 25.7 m^3/m of beach (or about 25,700 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in 11 months was 10-times this at 246.5 m^3/m of beach (or about 247,000 m^3/km of shoreline).

4.4 Patea

Patea Beach (site E) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 360 m of beach.

Figure 4-12: Patea Beach and profile sites (Google image).

Patea Beach is formed where the Patea River emerges at the coast (Figure 4-12). Here, the beach comprises a 600 m long strip of black sand about 90-110 m wide backed by foredunes about 5-10 m tall. Very high tides and waves can erode the dunes. Behind the foredune, sand has been blown inland to smother low topography and build transgressive dunes (lower left image). To the NW of this strip of beach (and also to the SE of the Patea River mouth), the beach is small and confined at the base of eroding 35 m tall near-vertical cliffs (Figure 4-13 lower right image).

The Patea River feeds sand to the coast. At the river entrance the training groynes intercept the longshore drift. The build-up of sand on the west wall of the groynes indicates a net transport of sediment from the NW to the SE. Wave-breaking patterns indicate sand bars offshore from the river mouth. As these bars change shape and move about during wave events and river floods they will afford changing shelter from wave energy to the shoreline in their lee and the beach will erode and accrete accordingly.

Figure 4-13: Views of Patea Beach.

Pits dug in the beach (Figure 4-14) show alternating layers of coarse and fine sediments made up of fine black sands and gravelly sands, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between.

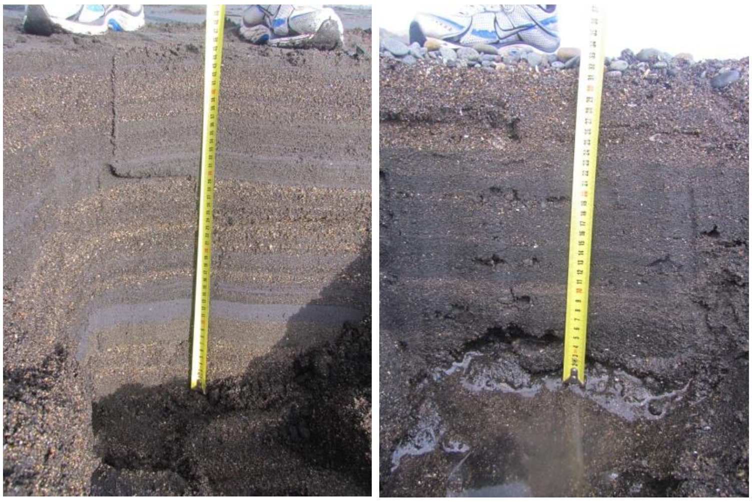

Figure 4-14: Pits dug in the beach showing alternating layers of fine and coarse material (scale in centimetres).

Observations show that the black sand layers on the upper beach can be formed during strong winds when they are concentrated as a lag on the beach surface. On the lower beach they can form as a lag during erosion of the beach face by swash and backwash of waves.

The grain size distribution of samples from the mid beach level is shown in the table below.

Table 4-4: Particle size of beach sediment from Patea. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Patea	1	Poorly sorted, gravelly, medium Sand	22	78	<1	1.343
Patea	2	Moderately sorted, slightly gravelly, coarse Sand	0	10	<1	0.581
Patea	3	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.476
Patea	4	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.477

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 0.8 to 2.0 m, and the beach face shows excursions back and forth of about 22 m, as sand comes and goes in response to wave events. Patterns of beach erosion and accretion are similar at profiles E1 and E2 in the SE showing erosion in September, build-up in October – November and erosion in December – January. Profiles E3 and E4 show build-up in August, erosion in September – October and erosion at the end of the record in March – April. A survey undertaken on 22 September following a storm showed quite different beach responses to the event at the 4 profile sites. While the beach built up on profile E1 in the SE, there was only minor erosion on E2 and more erosion on E3 and E4 (in the NW). This is interpreted to mean that the storm caused movement of a slug of sediment SE along the shore and toward the river mouth. Beach build-up was evidenced in the profile record by swash bars (to 0.8 m high and 50 m long) coming ashore. All the profiles showed a net reduction in beach volume over the 11 month survey period. Overall there was a net loss in beach sand volume of 15.9 m^3/m (or about 15,900 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in 11 months was 11-times this at 169.5 m^3/m of beach (or about 169, 500 m^3/km of shoreline).

4.5 Waverley

Waverley Beach (site D) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 400 m of shoreline.

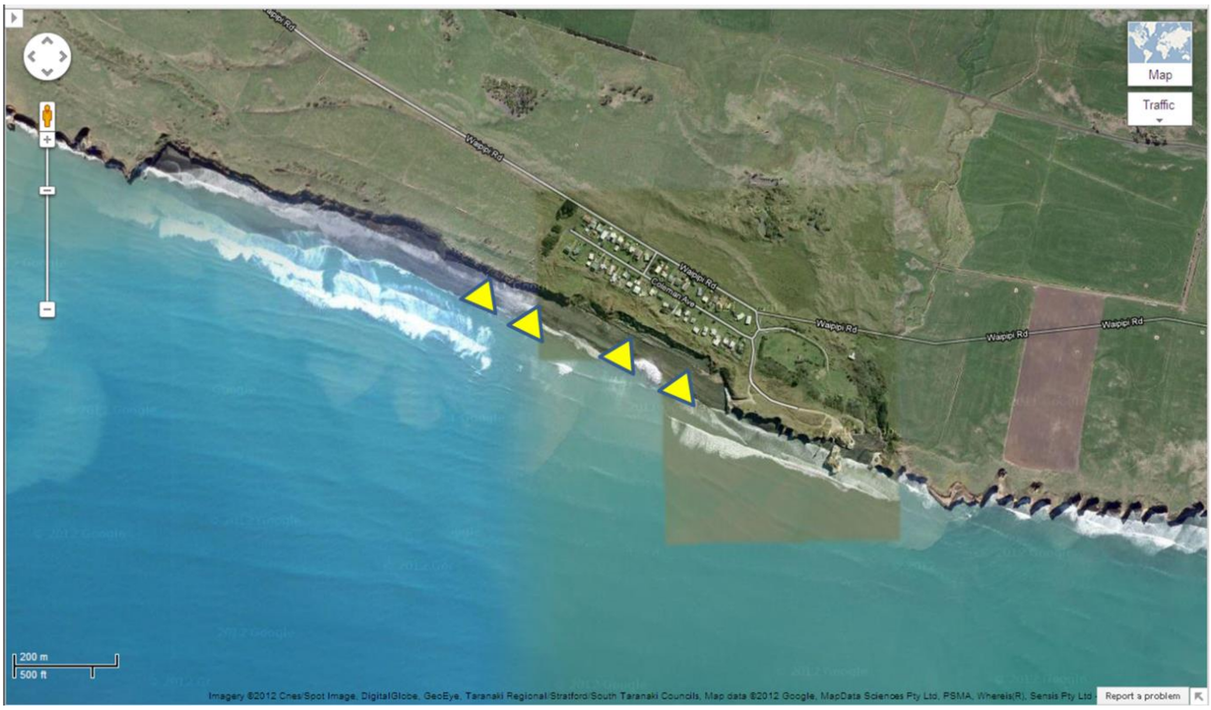

Figure 4-15: Waverley Beach and profile sites (Google image).

Waverley Beach is about 2 km long and 110 m wide and forms in a coastal re-entrant[4] where perhaps faulting in the cliffs[5] has allowed the cliffs to cut back almost 100 m further than the adjacent coast (Figure 4-15). The beach is composed primarily of black sand with small amounts of pebbles and cobbles strewn on the upper beach at the base of vertical 30 m tall and actively-eroding sea cliffs. Rockfalls and slumping from the cliff face provides sand and the small amounts of cobbles and pebbles to the beach. In the NW the beach profiles are situated against near-vertical cliffs, while in the SE they run up to slumped cliff. Large swash bars appear on the beach (Figure 4-16, top right image) as evidence that sand is coming ashore. There is some rocky shore platform exposed on the beach in the NW. There is little accommodation space for beach sand which appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves can reach right to the top of the beach and the toe of the cliffs which means there is no space for sand dunes to build out of the reach of waves. Ground water and surface water drains from cliffs and runs over and through the beach face to emerge near low tide level and pond behind the swash bars (Figure 4-16, top right and bottom right images).

[4] A prominent indentation in a coastline.
[5] The Waverley Fault Zone runs through this area (NZ Geological Survey map 1:250,000. Sheet 10 Wanganui 1st edition).

Figure 4-16: Views of Waverley Beach.

Pits dug in the beach (Figure 4-17) show alternating layers of mainly fine sediments made up of fine black sands and gravelly sands, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between. There is less gravelly sand in the beach at Waverley, than there is at some of the other sites.

Figure 4-17: Pits dug in the beach showing alternating layers of fine and coarse material (left pit is 40 cm deep, right pit is 30 cm deep).

The grain size distribution of samples from the mid beach level is shown in Table 4-5 below.

Table 4-5: Particle size of beach sediment from Waverley . The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Waverley	1	Moderately well sorted, medium Sand	0	100	<1	0.305
Waverley	2	Poorly sorted, gravelly, medium Sand	5	95	<1	0.732
Waverley	3	Poorly sorted, gravelly, medium Sand	10	90	<1	0.774
Waverley	4	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.463

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 0.8 to 2.0 m, and the beach face shows excursions back and forth of about 16 m, as sand comes and goes in response to wave events. Beach erosion and accretion patterns show little similarity at the four profile sites. A survey on 22 September following a storm showed accretion on profile D1 (in the SE) and erosion on profiles D2, D3 and D4 (in the NW). Over the 11 month survey record there was a net reduction in beach volume at profiles D1 and D3 and an increase at D2 and D4. The accretionary pulse that occurred in November on profile D4 (in the NW), appeared in December in profile D3, and in March in profiles D3 and D4 (in the SE). This pattern and observations on the beach are interpreted to mean that storms cause movement of slugs of sediment along the shore resulting in sand build-up and shoreline build-out in some places and retreat in others. Beach build-up is evidenced in the profile record by swash bars (up to 1.0 m tall and 50 m long) coming ashore on about half of the 11 profile surveys (Appendix A). Overall there was a net gain in beach sand volume of 4.7 m^3/m (or about 4,700 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in 11 months was 23-times this at 109.6 m^3/m (or about 109,600 m^3/km of shoreline).

4.6 Waiinu

Waiinu Beach (site C) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 400 m of shoreline.

Figure 4-18: Waiinu Beach (Google image).

Waiinu Beach lies in a small re-entrant on a prominent bulge of the coast (Figure 4-18). The profiles are situated to the NW of the re-entrant. Here the beach is about 90 – 110 m wide and comprised of black sand. Rocky shore platform is exposed at low tide (lower left image), and there is submerged reef in the nearshore. It has a well-developed and vegetated foredune 3 m tall. Sand has blown inland to build transgressive dunes over rising ground behind the foredunes. This inland area is now stabilised with farm pasture. Very high tides and waves erode the dune face. Swash bars are evidence of sand coming ashore to build the beach (Figure 4-19, upper left image). Ground water drains from under the foredune and through and over the beach face to emerge near low tide level (Figure 4-19, lower right image). The coast extending north for about 6 km to the Waitotara River is very similar.

Figure 4-19: Views of Waiinu Beach.

Pits dug in the beach (Figure 4-20) show alternating layers of coarse and fine sediments made up of fine black sands and gravelly sands, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between.

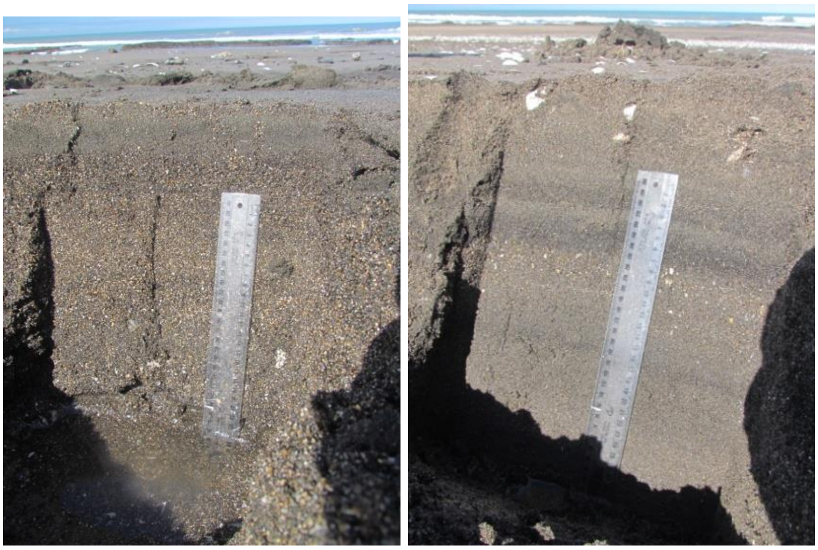

Figure 4-20: Pits dug in the beach showing alternating layers of fine and coarse material (ruler is 30 cm long).

The grain size distribution of samples from the mid beach level is shown in Table 4-6 below.

Table 4-6: Particle size of beach sediment from Waiinu. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Waiinu	1	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.574
Waiinu	2	Poorly sorted, slightly gravelly, coarse Sand	2	98	<1	0.783
Waiinu	3	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.537
Waiinu	4	Moderately sorted, slightly gravelly, medium Sand	0	100	<1	0.469

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 0.6 to 1.0 m, and the beach face shows excursions back and forth of about 22 m, as sand comes and goes in response to wave events. The patterns of beach erosion and accretion are very similar at profiles C1 and C2 in the SE showing erosion in September – October, accretion in November, and erosion in January – March. Profiles C3 and C4 to the NW show accretion from October – November, accretion from December – April and to the end of the record. The survey undertaken on 21 September 2011 following a storm showed only a small change at the four profile sites, with erosion at profiles C1 and C4 and accretion at profiles C2 and C3. This is interpreted to mean that the storm caused movement of a slug of sediment along the shore resulting in beach face build-out in some places and retreat at others (rather than retreat at all sites that might normally be expected following a storm). Beach build-up was evidenced in the profile record by swash bars (to 0.8 m tall and 50 m long) coming ashore. Over the 11 month survey record there was little net change in beach volume on C1, some erosion on C2, and accretion on C3 and C4. Overall there was a net loss in beach sand volume of 10.1 m^3/m (or about 10,100 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in 11 months was 10-times this at 100.5 m^3/m (or about 100,500 m^3/km of shoreline).

4.7 Ototoka

Ototoka Beach (site B) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 630 m of shoreline.

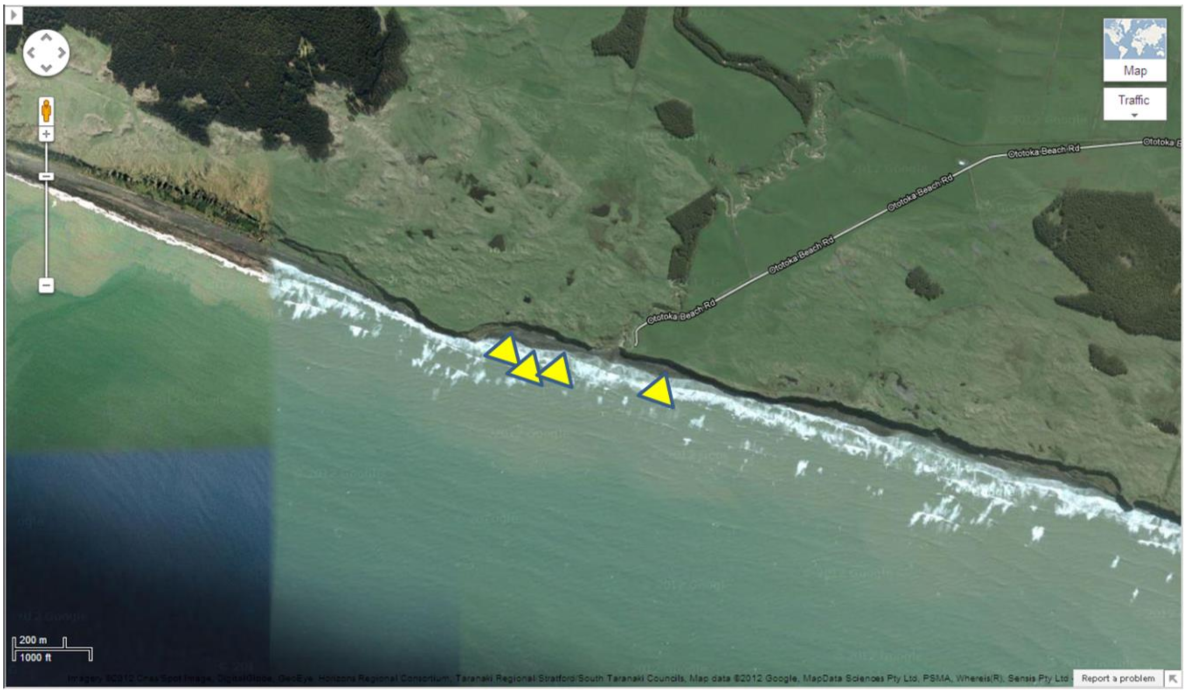

Figure 4-21: Ototoka Beach and profile sites (Google image).

Ototoka Beach is formed where a small stream cuts through coastal cliffs and emerges on the beach (Figure 4-21). Here, a largely sandy beach about 100 – 130 m wide, with an incipient foredune in places, is built in front of near-vertical 40 m tall sea cliffs that are stabilised to a large degree by vegetation. The upper beach is commonly strewn with logs and wood debris from nearby rivers (Figure 4-22, upper left and right images). A rocky reef shore platform is exposed in places on the beach face in the NW. There is little accommodation space for beach sand which appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. On occasions there is a well-developed nearshore bar (Figure 4-22, upper left image) providing evidence that more sand is stored offshore. Very high tides and waves can reach the top of the beach and the toe of the cliffs in places, which means there is only limited space for sand dunes to build out of the reach of waves. Ground water and surface water drains from cliffs and runs through the beach face to emerge near low tide level as springs with persistent upwelling (Figure 4-22, lower right image).

Figure 4-22: Views of Ototoka Beach.

Pits dug in the beach (Figure 4-23) show alternating layers of coarse and fine sediments made up of fine black sands and shelly gravelly sands and gravels, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in-between.

Figure 4-23: Pits dug in the beach showing alternating layers of fine and coarse material (ruler is 30 cm long).

The grain size distribution of samples from the mid beach level is shown in Table 4-7 below.

Table 4-7: Particle size of beach sediment from Ototoka. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Ototoka	1	Moderately sorted, slightly gravelly, medium Sand	1	99	<1	0.467
Ototoka	2	Moderately sorted, slightly gravelly, medium Sand	3	97	<1	0.591
Ototoka	3	Moderately sorted, slightly gravelly, medium Sand	1	99	<1	0.430
Ototoka	4	Poorly sorted, sandy, fine Gravel	33	67	<1	1.431

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 0.6 to 1.7 m, and the beach face shows excursions back and forth of about 29 m, as sand comes and goes in response to wave events. There is quite a lot of variability between the timing of the accretion and erosion on the profiles. Profile B1 shows erosion in September, while adjacent profile B2 shows mostly accretion in September and profile B3 little change. Profile B1 shows erosion from October. Profiles B2, B3 and B4 are close together and to the NW of the small stream and show some similarity with the erosion occurring in early November at profile B4 in the NW, then moving to B3 in December and then B2 (in the SE) in January. Field observations show that this may be related to slugs of sand moving along shore. Beach build-up is evidenced in the profile record by large sand waves (to 1.0 m tall and 100 m long) coming ashore. The survey undertaken on 21 September following a storm showed erosion at profiles B1 and B3 and accretion at profiles B2 and B3. Over the 11 month record there was a net reduction in sand volume on all profiles. The changes in sand volume on the profiles suggest that slugs of sand (transient accretion) are moving west to east (from profile B4 in the NW to profile B1 in the SE) along the shore. Overall there was a net loss in beach sand volume recorded in 11 months of 6.1 m^3/m (or about 6,100 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in the 11 surveys was 33-times this at 205.1 m^3/m (or about 205,100 m^3/km of shoreline).

4.8 Kai Iwi

Kai Iwi Beach (site A) is shown in the images below and graphs and statistics from beach profile analysis are presented in Appendices A and B respectively. The four profiles span 420 m of shoreline.

Figure 4-24: Kai Iwi Beach and profile sites (Google image).

Kai Iwi Beach is formed where a stream cuts through coastal cliffs and emerges on the beach (Figure 4-24). Here, a largely sandy beach about 110 – 120 m wide is built in front of near-vertical 40 m tall sea cliffs that are slumping and feeding large slabs of rock and rubble to the upper beach at the base of the cliffs. There is little accommodation space for beach sand, which appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. Very high tides and waves can reach the top of the beach and the toe of the cliffs which means there is no space for sand dunes to build out of the reach of waves. Ground water and surface water drains from cliffs and runs through the beach face to emerge near low tide level.

Figure 4-25: Views of Kai Iwi Beach.

Pits dug in the beach (Figure 4-26) show alternating layers of coarse and fine sediments made up of fine black sands and shelly gravelly sands and gravels, providing evidence that the beach face is substantially reworked and sorted during wave events and the calmer periods in between.

Figure 4-26: Pits dug in the beach showing alternating layers of fine and coarse material (ruler is 30 cm long).

The gravelly sand layers seen in the pits have been observed on the lower beach face at times of intense swash and backwash during storm events. There is less black sand in the beach at this site than at any of the other sites where profiles were measured. This is expected as this site is furthest from the Taranaki Ring Plain and the ultimate source of black sands.

The grain size distribution of samples from the mid beach level is shown in Table 4-8 below.

Table 4-8: Particle size of beach sediment from Kai Iwi. The profiles number 1 to 4 and east to west.

Site	Profile	Sediment type	Gravel %	Sand %	Mud %	Mean grain size (mm)
Kai Iwi	1	Moderately well sorted, slightly gravelly, medium Sand	1	99	<1	0.394
Kai Iwi	2	Poorly sorted, gravelly, medium Sand	10	90	<1	0.630
Kai Iwi	3	Poorly sorted, gravelly, coarse Sand	6	94	<1	0.691
Kai Iwi	4	Poorly sorted, gravelly, coarse Sand	6	94	<1	0.810

The 2011 – 2012 beach profile data show a very active beach. The beach elevation fluctuates up and down 1.4 to 2.1 m, and the beach face shows excursions back and forth of about 35 m, as sand comes and goes in response to wave events. Kai Iwi is the only site where the pattern of erosion and accretion is similar at all four profile sites. It shows erosion from June – September /October, and accretion through to January, followed by a smaller amount of erosion or accretion after that. Beach build-up is evidenced in the profile record by very large swash bars (to 1.5 m tall and 70 m long) coming ashore on about half of the occasions the profiles were surveyed (Fig. 4–24, upper right image). The survey undertaken on 21 September following a storm showed erosion on all four profiles with the greatest erosion at profile A1 in the SE. The net change in sand volume over the 11 surveys was for an overall reduction at profiles A1 and A4 and an increase at profiles A2 and A3. Over the 11 month record the changes in sand volume on the profiles suggest that a slug of sand (transient accretion) moved NW to SE (from profile A4 to profile A1) along the shore. Overall there was a net loss in beach sand volume recorded in 11 months of 5.3 m^3/m (or about 5,300 m^3/km of shoreline). However the minimum amount of sand moving on and off the beach recorded in the 11 surveys was 39-times this at 204.3 m^3/m (or about 203,300 m^3/km of shoreline).

5 Geomorphology and coastal processes

5.1 Coastal geomorphology

The northern area (Opunake to Inaha) is dominated by the Mount Taranaki Ring Plain volcanics and lahar deposits. The lahar deposits extend south to about the Inaha Stream near Hawera. Uplift of the ring plain and changes in sea level plus the energetic westerly wave climate have caused parts of the coast to be cliffed, although the cliffs are generally small and eroding slowly. In places, the cliffs are taller where they are capped by erodible overlying sedimentary sections. This shoreline consists mainly of cliffs and rocky, wave-cut intertidal platforms with a thin veneer of sand or gravelly sand, cobbles or boulders. Areas of rocky seabed with thin, intermittent sand cover are common in the nearshore. Terrestrial sediment inputs to this section of shoreline are dominated by erosion of volcanic materials from Mount Taranaki (TRC 2009). There are many small streams, but few rivers, resulting in only small quantities of sediment being delivered to the coast and limited occurrence of sand beaches and dunes at the shore.

The southern area (Inaha Stream to Wanganui) has seen continual tectonic uplift (McGlone et al. 1984) to produce a coast characterised by almost continuous near-vertical, 30 – 40m tall, sedimentary cliffs. Sand beaches occur at the base of the cliffs. In places there is reef exposed in the low tide part of the beach and submerged offshore.

The cliffs are composed of soft sedimentary material, largely Pliocene Wanganui Series mudstones, sandstones, shellbeds, limestone and conglomerates. In places this is capped with Pleistocene conglomerates, marine sand, dune sand, volcanic sand and lignite bands. The cliff face erodes catastrophically by slumping, also aided by groundwater seepage though the strata and joints in the cliffs, large waves undercutting the base and removing slumped material and perhaps tectonic activity such as earthquakes. Slumped sediment and rock protects the cliff base until wave action removes the debris (Cowie et al. 2009, TRC 2009). Our field observations made during monthly profile surveys, suggest that the soft sedimentary sandstone and mudstone components of this material breaks down rapidly and that slumped deposits seen at the toe of the cliffs on one survey, may have been partially washed away by waves on a subsequent visit. The actual rate of breakdown of cliff material and the total supply of sandy and gravelly material to the beaches from cliff erosion is unknown.

Terrestrial sediment inputs to Opunake to Wanganui shoreline comes primarily from the erosion of inland sedimentary catchments and delivery to the coast by the rivers. Estimates of the suspended sediment yield from the major rivers is given in Table 5-1.

Table 5-1: Suspended sediment inputs from the rivers flowing into the study area. The mean flow is a cumulative catchment average. The data is sourced from NIWA's WRENZ model (http://wrenz.niwa.co.nz/webmodel/), and has been compiled in a manner described in Hicks et al. 2011).

River	Upstream area (km^2)	Mean flow (m/s)	Sediment yield (t/yr)
Waiaua River (Opunake)	46.4	3.6	4900
Kaupokonui Stream	146.3	8.6	9700
Waingongoro R (Ohawe)	233.1	7.8	9100
Tangahoe River	285.1	4.2	43900
Manawapou River	120.9	1.9	15000
Patea River	1048.5	30.4	310600
Whenuakura River	465.3	9.9	275900
Waitotara River	1162.0	23.3	475400
Kai Iwi Stream	191.0	1.8	16900
Whanganui River	7113.8	229.0	4699800

5.2 Coastal sand transport

Longshore sand transport is driven primarily by the waves arriving at an angle to the shore. Most wave energy in the South Taranaki Bight comes from large southwest swells from the Southern Ocean and locally generated wind waves from the Tasman Sea that vary in size and direction with season. Numerical modelling was used to provide a 20-year hindcast of wave conditions for the South Taranaki Bight (MacDiarmid et al. 2010). It showed that the largest wave heights are found off the western end of the Taranaki Peninsula, decreasing further south with increasing shelter from prevailing SW swell. This is also seen in the corresponding average of wave energy flux, which is a vector quantity reflecting the magnitude and direction of energy transfer by the waves. This shows relatively strong energy transfer, principally from the WSW, at the northern end of the South Taranaki Bight, while further south, the more southerly energy components become blocked. The orientation of energy flux relative to the coast is also significant, as wave energy reaching the coast at an oblique angle (i.e., not perpendicular to the coast) can drive longshore sediment transport. It would therefore be expected that in the northern part of the Bight, from Opunake to south of the Wanganui River, wave-driven processes will tend to transport sand along the coast towards the southeast. Locally, the incident wave angle (wave attack) is affected by offshore bathymetry which is quite complex (Fig. 1-1). In the nearshore, wave angle and breaking are further affected by shore platform and rock reef. The build-up of a fillet of sand on the NW flank of the training works at the entrance to the Patea River, and river plumes moving in a SE direction (MacDiarmid et al. 2010) are indicative that net sand transport is NW to SE along the shore. There is no local information on rates of sand transport along the shore. Further south on the Manawatu coast, northward transport will predominate. The monthly mean values of significant wave height and wave energy flux show a seasonal cycle with mean wave heights reaching a maximum in late winter and a minimum in late summer. At a site offshore from Waverley for instance, the 20-year mean significant wave height is 1.8 m, but with monthly means varying between 1.4 m in February and 2.1 m in August.

Sand transport can be particularly large at times of storms when large waves create a surf zone and corridor for sand transport more than 500 m wide. Under these conditions sand is moved in pulses or slugs along the shore. Sand moving in this wide corridor can bypass small headlands and promontories and 'jump' from beach to beach as it is driven along the shore. Sand is also stripped from the beaches via rip channels and temporarily stored in bars and banks in the nearshore. These bars and banks cause the waves to beak offshore, dissipating energy and thus serve to protect the beach from erosion. In quieter periods of long low swell sediment, is returned by the wave generated currents from the seabed to the shore. Such bars are seen coming ashore as swash bars on the lower to mid-beach and are visible in many of the profile records and in field observations as well.

5.3 Beach morphology and sand storage

An important characteristic of the South Taranaki Bight coast is the lack of accommodation space for sand. In order for sand to be deposited, there has to be space available for it to accumulate in. On the South Taranaki Bight coast there are few bays, estuaries, large coastal re-entrants or headlands, where sand can accumulate and be stored, for example as wide beaches and dune systems that can develop out of the reach of waves.

Sand is stored in small shallow coastal re-entrants that occur along about 70% of the coast, as small narrow (about 100 m wide) beaches built in front of near-vertical 35–50 m tall seacliffs. There is little accommodation space for beach sand, which just appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line. On occasions sand is stored in a nearshore bar. The rocky shore platform is sometimes exposed at low tide at the base of the beach. Some of these re-entrants form where streams and small rivers emerge on the beach (e.g., beach profile sites Ohawe, Hawera, Manawapou, Kai Iwi). Others form where the geology allows that section of the coastal cliffs to erode and retreat more rapidly (e.g., beach profile site Ototoka) than adjacent sections of cliffs.

In the north at Ohawe and Hawera, the beach sediments (Table 5-2) are overall coarser than those to the south, being largely poorly sorted gravelly medium to coarse sands and fine gravels, with much of the coarser material appearing to derive from cliff collapse. In the south the beaches are sandier being primarily moderately sorted gravelly medium sands. In the north at Ohawe and Hawera the beaches also tend to be narrower and steeper (ranging 4 – 7 degrees) than the beaches to the south where the beach slope of the order of 2 – 4 degrees (Table 5-2) which is a reflection of the differences in grain size of the sediment (coarse sediment builds steeper beaches).

Table 5-2: **Grain size and average beach slope at the beach profile sites.**

Site	Profile	Sediment type	Average beach slope (degrees) between 0.0 and 3.0m elevation
Ohawe	1	Moderately sorted, slightly gravelly, medium Sand	3.8
Ohawe	2	Poorly sorted, gravelly, medium Sand	4.9
Ohawe	3	Poorly sorted, gravelly, medium Sand	4.6
Ohawe	4	Moderately sorted, slightly gravelly, medium Sand	4.6
Hawera	1	Poorly sorted, gravelly, coarse Sand	5.9
Hawera	2	Poorly sorted, gravelly, coarse Sand	6.9
Hawera	3	Poorly sorted, gravelly, medium Sand	4.9
Hawera	4	Poorly sorted, sandy, fine Gravel	4.9
Manawapou	1	Moderately sorted, slightly gravelly, medium Sand	5.1
Manawapou	2	Moderately sorted, slightly gravelly, coarse Sand	4.6
Manawapou	3	Moderately sorted, slightly gravelly, medium Sand	3.8
Manawapou	4	Moderately sorted, slightly gravelly, medium Sand	5.7
Patea	1	Poorly sorted, gravelly, medium Sand	3.8
Patea	2	Moderately sorted, slightly gravelly, coarse Sand	3.2
Patea	3	Moderately sorted, slightly gravelly, medium Sand	4.0
Patea	4	Moderately sorted, slightly gravelly, medium Sand	4.1
Waverley	1	Moderately well sorted, medium Sand	3.0
Waverley	2	Poorly sorted, gravelly, medium Sand	2.8
Waverley	3	Poorly sorted, gravelly, medium Sand	3.4
Waverley	4	Moderately sorted, slightly gravelly, medium Sand	2.5
Waiinu	1	Moderately sorted, slightly gravelly, medium Sand	3.6
Waiinu	2	Poorly sorted, slightly gravelly, coarse Sand	3.4
Waiinu	3	Moderately sorted, slightly gravelly, medium Sand	2.6
Waiinu	4	Moderately sorted, slightly gravelly, medium Sand	2.9
Ototoka	1	Moderately sorted, slightly gravelly, medium Sand	2.1
Ototoka	2	Moderately sorted, slightly gravelly, medium Sand	3.1
Ototoka	3	Moderately sorted, slightly gravelly, medium Sand	3.1
Ototoka	4	Poorly sorted, sandy, fine Gravel	3.0
Kai Iwi	1	Moderately well sorted, slightly gravelly, medium Sand	2.4
Kai Iwi	2	Poorly sorted, gravelly, medium Sand	2.2
Kai Iwi	3	Poorly sorted, gravelly, coarse Sand	1.8
Kai Iwi	4	Poorly sorted, gravelly, coarse Sand	2.0

As our beach profile data, show the sediment in these beaches is very mobile. While limited accommodation space sometimes permits incipient (small, unvegetated) dunes to form in the re-entrant at the stream mouths, there is no space for dunes to be accommodated at the base of the cliffs. Consequently high tides, combined with storm surge and large waves reach right up to the cliffs and the entire beach is subjected to erosion, enhanced by backwash from the cliffs. Erosion is further enhanced by ground water and surface water flow originating in the cliffs and flowing though the beach where it emerges as seepage lines and springs at mid to low tide level (Wet beaches erode more easily than dry beaches because of their high water content). Accommodation space in this situation is limited by the tall cliffs.

Sand is stored in foredunes and transgressive dunes along a sandy section of coast that runs from the Patea River to about Waiinu (e.g., beach profile sites Waiinu). Here, dunes front a bulge in the coast. Sand is stored in the beach and foredune and also in transgressive dunes that are formed when sand picked-up from the beach by strong winds, prevalent on this coast, is blown inland to smother low lying topography and rising ground. These inland dunes are now, in most part, farm pasture. Accommodation space is made available in this situation on top of the low lying topography.

A small amount of sand is stored in bars at the mouths of the rivers (e.g., beach profile site Patea).

With the exception of the sand stored in the transgressive dunes, the sand storage on beaches in the South Taranaki Bight is rather transient in a system of highly connected sand storage units. Sand is exchanged on and off the shore between the beaches and the nearshore bars. Sand is driven to the NW and SE along the shore depending on the wave direction, but primarily to the SE. Big waves and a surf zone 100's of metres wide, provide a highway for sand to move from re-entrant to re-entrant along the shore and bypass the river mouths.

5.4 Coastal stability

Historical shoreline change is used here to describe changes in shoreline position that have taken place over timescales of decades. The shoreline in the South Taranaki Bight contains sections of tall near-vertical cliffs which are fronted by small beaches in places and sections of beach backed by sand dunes. Shoreline as used in this report refers to either the toe of the cliffs or the mean high water spring (MHWS) tide level which is often estimated as the seaward boundary of vegetation when survey marks are not available. Coastal accretion is defined as 'the product of deposition of material at the shoreline, leading to a gain of land as the shoreline advances seaward'. Coastal erosion is defined as 'the process of episodic removal of material at the shoreline leading to a loss of land as the shoreline retreats landward', which is the result of work by the sea, the wind, migrating river mouths and tidal inlets, coastal landslides and tectonics (TRC 2009). Stable shorelines are those where the net erosion rate is less than 0.02 m/year over approximately the last one hundred years (TRC 2009).

The stability of the shorelines is influenced principally by: (1) the geology (whether the shore is unconsolidated and erodible or hard rock), (2) climatic factors such as wind, waves, rain and runoff and (3) the quantity of sediment is being delivered to the coast by rivers, sea cliff erosion and along-shore and cross-shore transport. The stability of shorelines is also influenced by human activities such as the planting or removal of vegetation in dune areas, catchment use change, sand extraction for aggregate or minerals and structures on the coast such as seawalls and training works at river mouths. These factors interact to modify the shoreline over many timescales including days, weeks, seasons, years, decades and longer. Considering interannual variability, TRC (2009) reports erosion occurs mainly during the winter (May – August) although some autumn and spring storms also contribute to erosion. While it is common for east coast beaches to build over the summer months and erode in the winter; there is a lack of beach profile data to confirm a similar pattern for the South Taranaki Bight. Our short (June 2011 to April 2012) beach profile record showed no evidence of any seasonal pattern. Instead, it showed considerable variation between the eight sites along the shore (Appendix A). The South Taranaki Bight beaches erode and accrete differently under similar storm conditions, and over just a few kilometres, due to local various factors. These include the geology, coastal orientation, how the incident wave angle (wave attack) is affected by offshore bathymetry (Fig. 1-1), effects of exposed shore platform and offshore reef on wave-breaking and direction, interactions between headlands, offshore bars, currents, waves, sediment supply from rivers and dune management (TRC 2009). Hard shorelines erode slowly, but unconsolidated shore can erode or retreat depending on sediment supply and forcing conditions.

6 Discussion and conclusions

The cliffed shore of the coast between Inaha and Wanganui has experienced erosion throughout the Holocene. Measurements of shoreline retreat in historical times show the shore has been eroding at rates of 0.05 to 1.1 m/yr. Much of the shoreline including the sections from Inaha to Patea and Waitotara to Wanganui, comprises 30 – 40 m tall, near vertical, soft sedimentary cliffs that are actively eroding through catastrophic failure and slumping. Narrow sandy beaches fronting the cliffs provide little protection from wave action and erosion.

On the coast between Patea and Waitotara/Waiinu, at a prominent bulge of the coast, there is a lot more sand in storage. Here the beach has a well-developed and vegetated foredune up to 3 m tall and sand has blown inland to build transgressive dunes over rising ground behind the foredunes. This area is now farm pasture. However there are no historical measurements of erosion or accretion on the shore, perhaps because of limited road access to this section.

On the Ohawe to Kai Iwi coastal stretch about 70% of the 70 km-long coast has high coastal cliffs fronted by small narrow largely sandy beaches. On the other 30% there are larger quantities of sand stored in sand dunes and part of the active beach system. Strong winds on this coast can drive sand inland over low lying topography to form transgressive dunes that are now largely stabilised under farm pasture.

Narrow, largely sandy beaches, fronting 30 – 40 m tall near-vertical cliffs, or sometimes located in small coastal re-entrants such as stream and river mouths, are a feature of about 70% of this coast. While on the surface the beaches often appear sandy, digging into the beach reveals layers of coarser gravelly sands and gravels as lag deposits (and in some cases not much black sand component), providing evidence that the beach face is fed from time to time by coarse cliff erosion debris and also reworked and sorted during wave events and the calmer periods in between. These beaches are characterised by small accommodation space and storage of sediment because of the tall cliffs. The beach appears to form a thin veneer, possibly only metres thick over the rocky shore platform left by the retreating cliff line, and there is generally no space for a dune to form. Although the beaches have only a small storage of sand, the beach profile data show there is a very high flux of sand through the system. The beach elevation goes up and down 1 to 2 m and the beach face oscillates in and out about 20 – 40 m over time scales of weeks and months. Sand also moves back and forth in swash bars between the nearshore bars, and the beach and alongshore as slugs of sediment in low broad shore normal bars. Storms do not always result in erosion on all parts of the beach, as a consequence of these pulses of sand moving along shore. The beaches are continually changing and almost ephemeral features. This highly variable geomorphology is driven by the large waves on this coast that run right to the top of the beach in storms and high tides. Reworking of the beach is also aided by backwash off the cliffs, and further enhanced by ground water and surface water flow from the cliffs through the beach.

Changes in sand volumes measured by beach profile surveys at the eight sites between Ohawe and Kai Iwi over the period June 2011 to April 2012 show that the net change in beach volume and sand storage varies from erosion at some sites to accretion at others. There is no pattern of change in erosion and accretion along the shore. The total movements of sand on and off the beach over the same period were of the order of at least 6-times to 39-times greater than the net change in sand storage.

Table 6-1: Sand volume changes from beach profile data - June 2011 to April 2012.

Site	Length of beach spanned by profiles	Net change in beach volume (m^3/km of shoreline)	Total amount of sand moving on and off the beach (m^3/km of shoreline)
Ohawe	500	+23,200	137,000
Hawera	530	-7,300	67,000
Manawapou	680	+25,700	247,000
Patea	360	-15,900	169,500
Waverley	400	+4,700	109,600
Waiinu	400	-10,100	100,500
Ototoka	630	-6,100	205,100
Kai Iwi	420	-5,300	203,300

The picture we see is one of large variability in beach morphology, small net storage of sand on the beaches and large quantities of sand being exchanged within the beach systems.

Information relating to TTR's additional scientific work undertaken since 2014 has been provided and the conclusions is this report remain valid.

7 Acknowledgements

We thank Chris Ormandy, Margret Bellingham, Gareth van Assema, Mike Carson and Scott Edhouse who assisted in the profile surveying. We would also like to thank Glenys Crocker for processing the beach sediments.

We thank Dr Murray Hicks for his very useful comments and review of this report.

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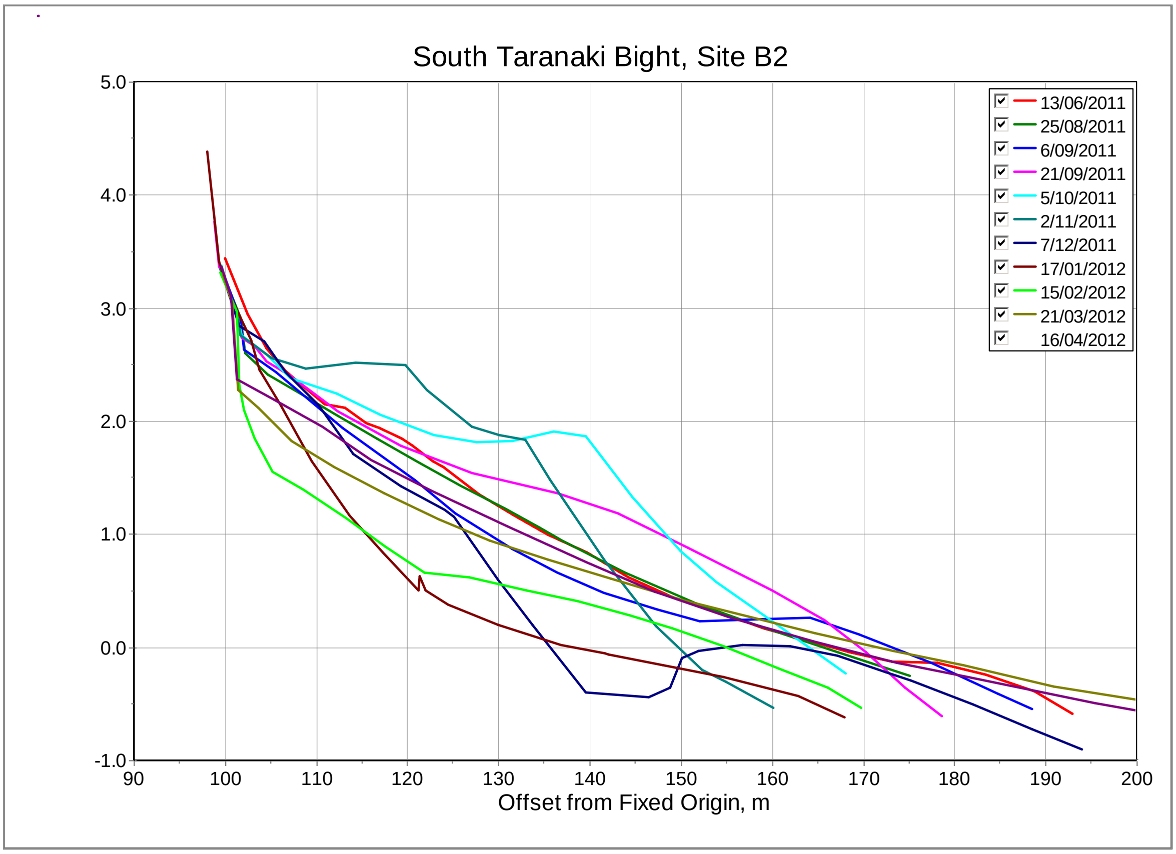
Appendix A Beach profile summary plots for all profiles from BPAT.

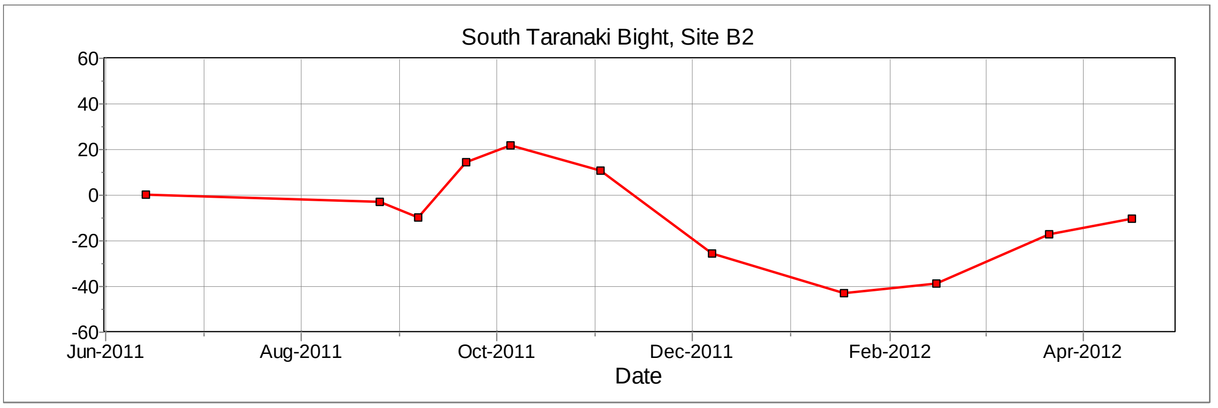
The profile data was edited and analysed using NIWA's beach profile analysis toolbox (BPAT) which provides graphs of profile shape and statistics of shoreline movement and sediment volume changes. The data was edited to remove large rocks from the profiles so that the data would reflect changes in the volume of unconsolidated beach sediment (i.e., mostly sand and gravel).

The BPAT 'spaghetti' plots of profiles (figure below) show the actual survey profiles and how the elevation (m above a datum, where 0 = Taranaki MSL) of the beach changes with distance (m from a start point) between the dune/high tide and low tide levels. Comparing the lines of two individual surveys shows the changes in elevation in the beach the two surveys and also the excursion (the amount of horizontal back and forth movement) of the beach face. The plot of all the profiles together displays the range of fluctuation over the entire survey record. The plots also show beach berms[6] building on the upper beach above high water and swash bars[7] on the lower beach. Swash bars typically signify shoreward migrating pulses of sand.

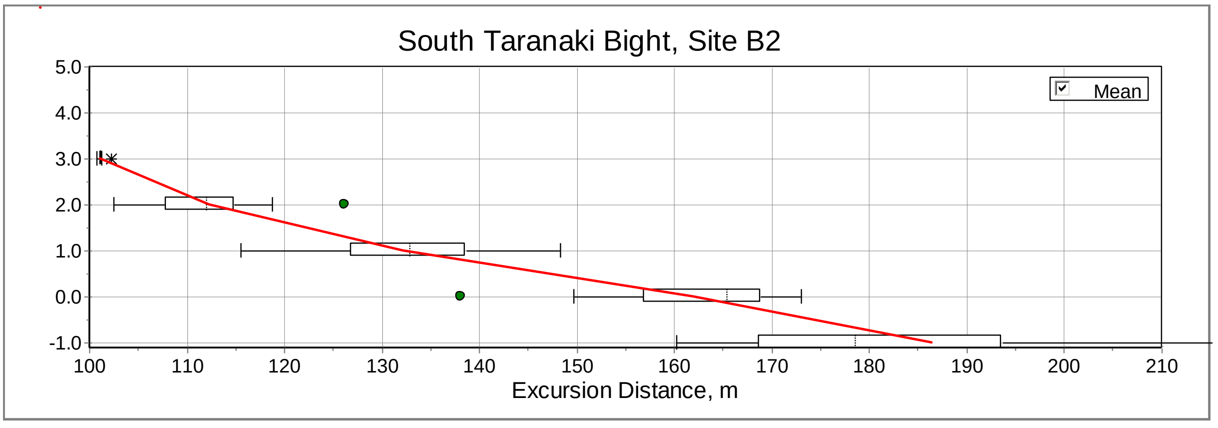


[6] Nearly horizontal plateaus on the beach face or backshore, formed by the deposition of sand by wave action.
[7] Low broad sandy bars formed by sediment in the surf and swash zones, separated by linear depressions, or runnels, running parallel to the shore.

The BPAT beach volume (cut/fill) plots (figure below) show how the volume of sand (m^3/m of beach length) stored in the beach (above a reference elevation or datum) changes over time, and also phases of erosion (cut-down) and accretion (build-up).

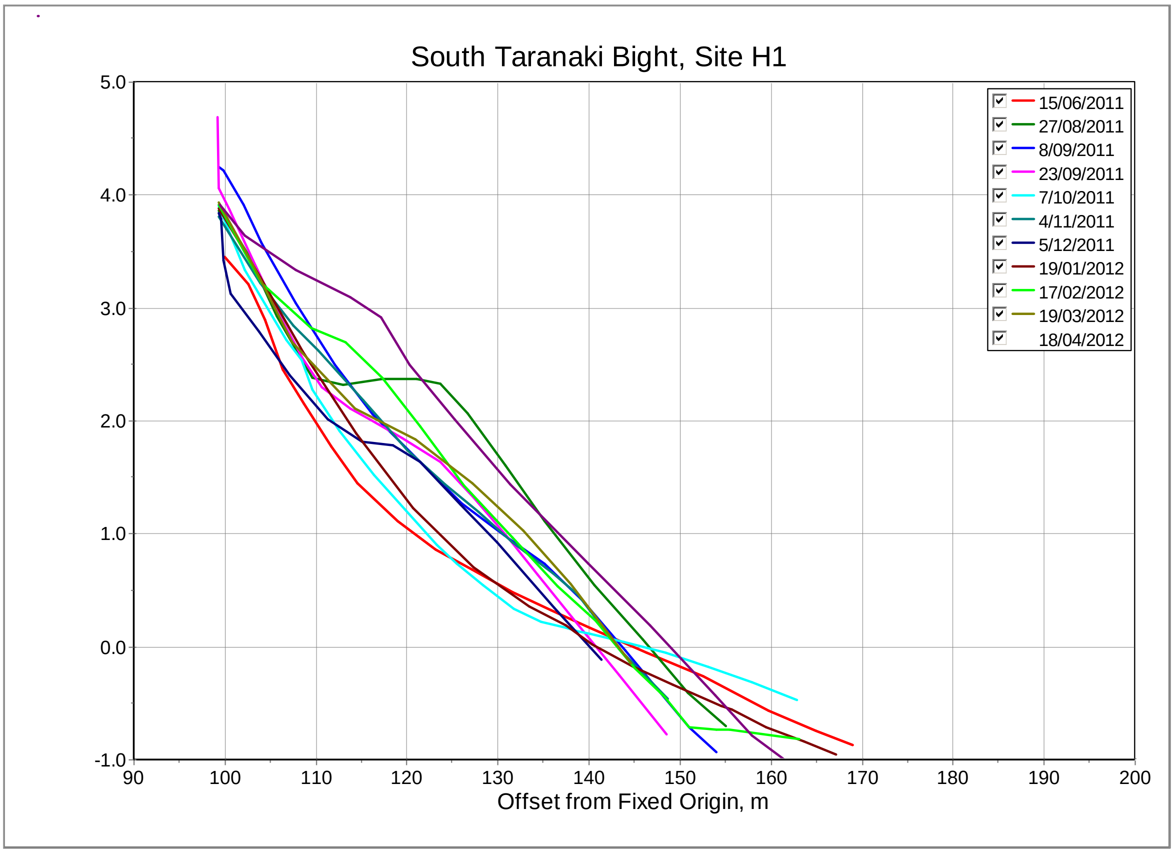


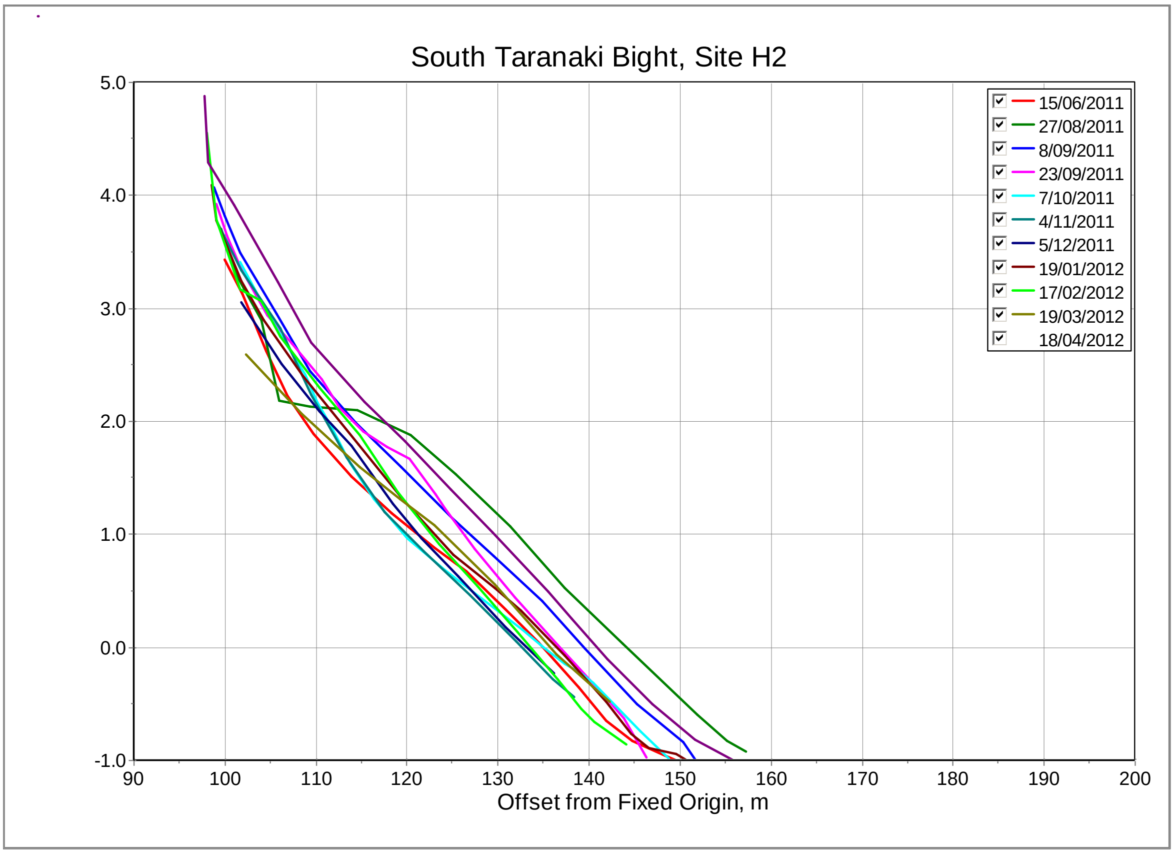
The BPAT 'box-and-whisker' excursion distance plots (figure below) show the amount of horizontal back and forth movement of the beach face at selected heights above a datum. The example below shows a very small amount of back and forth movement of the beach face on the upper beach (at 3 m elevation) and more back and forth movement (about 32 m) on the mid-beach (at 1.0 m elevation). The left and right hand end of the box represent the 25th and 75th percentile. The ends of the whiskers represent the minimum and maximum of the data. Any data not included between the whiskers are plotted as an outlier with a dot or star. The red line defines the mean profile shape.

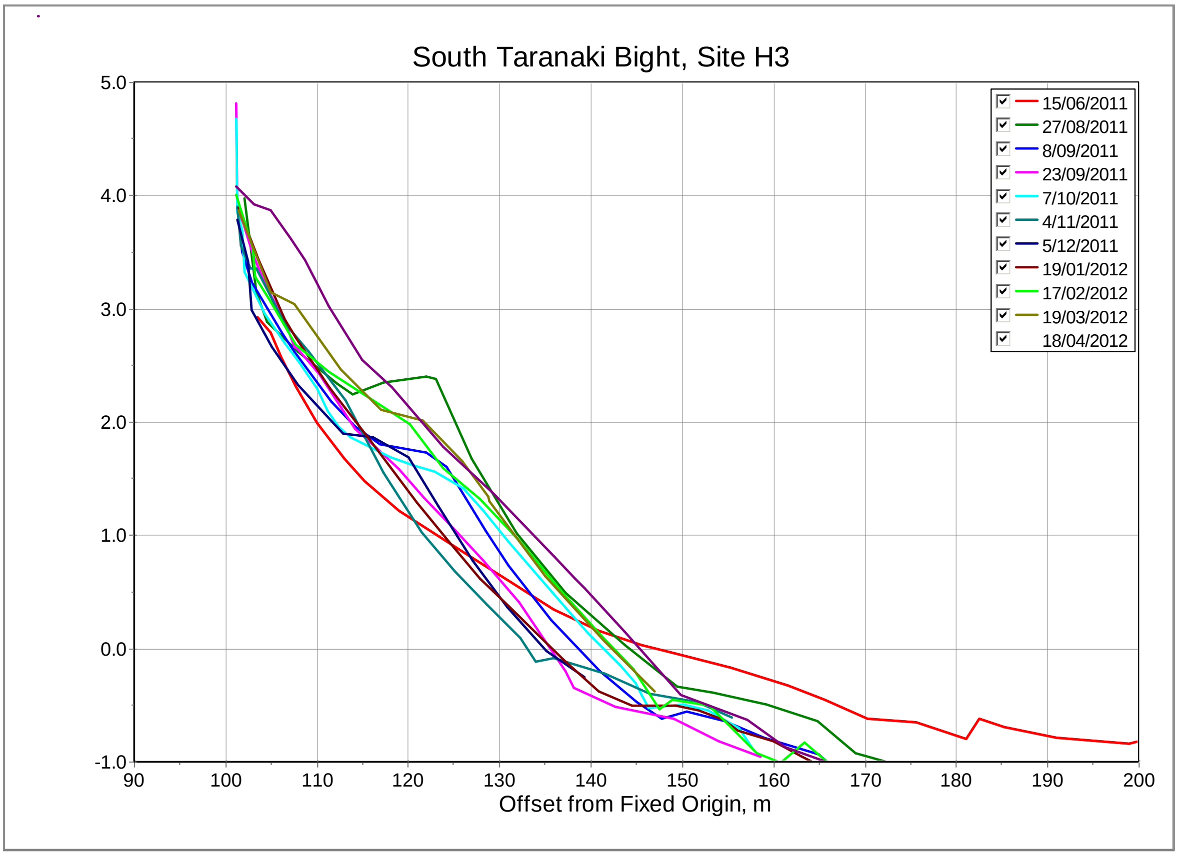


BPAT also tabulates the survey data and statistics from which the graphs are derived. These tables and graphs are the source of the data in Appendix B.

Ohawe – Site H - beach profile plots



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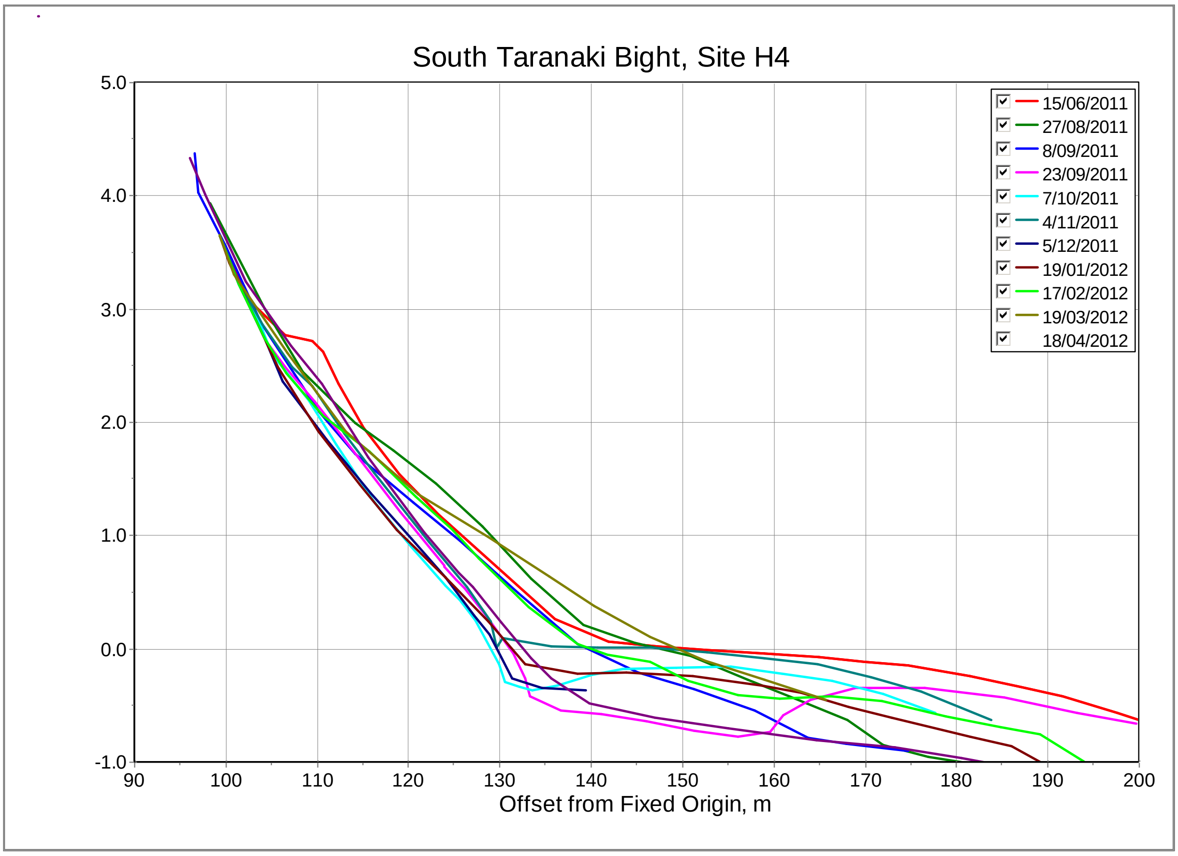
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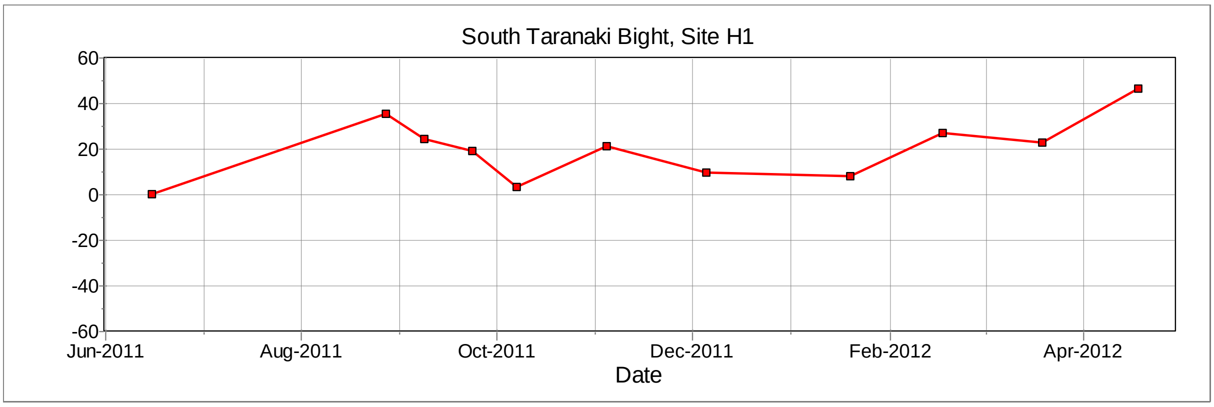
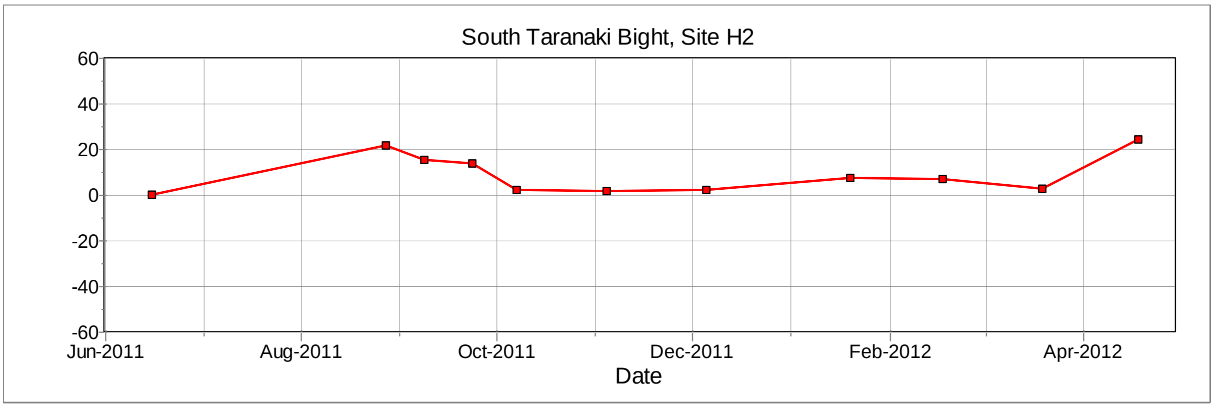
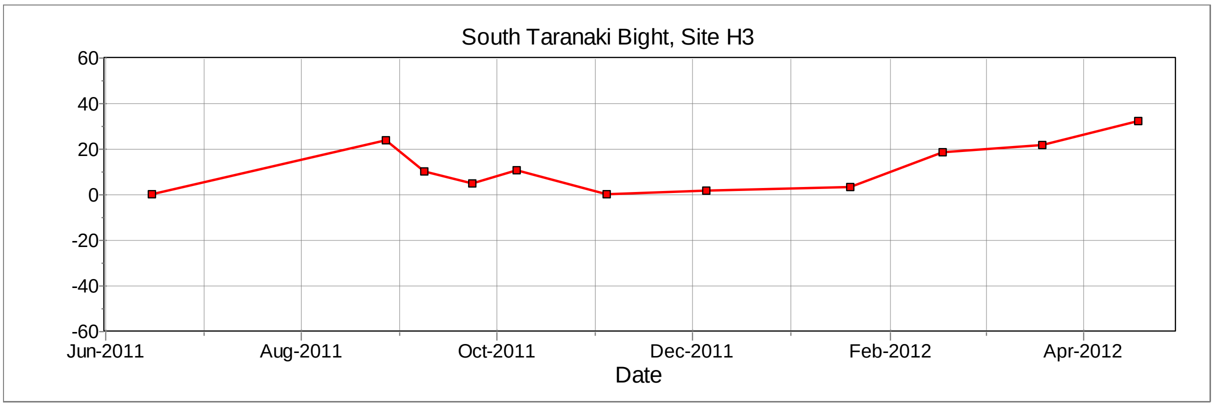
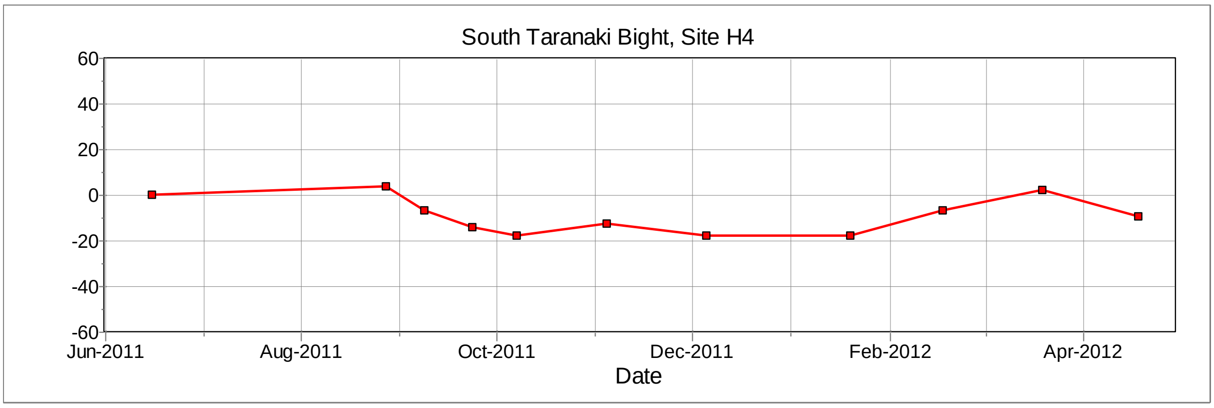
Ohawe - beach volume change (cut/fill) plots

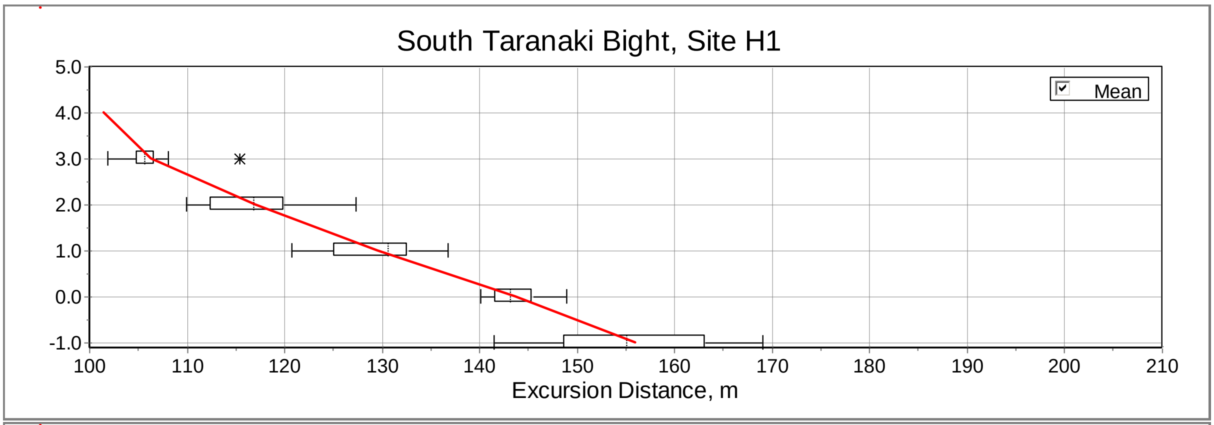


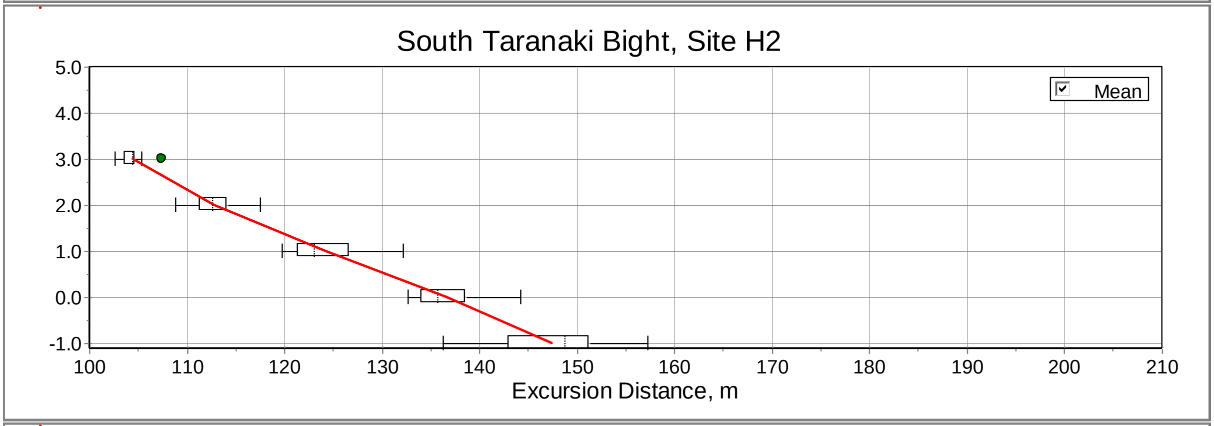


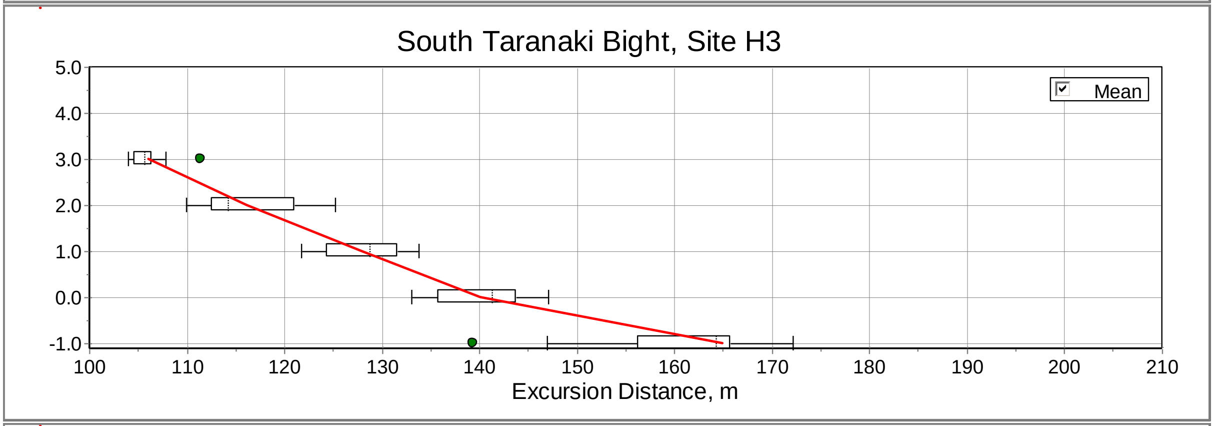


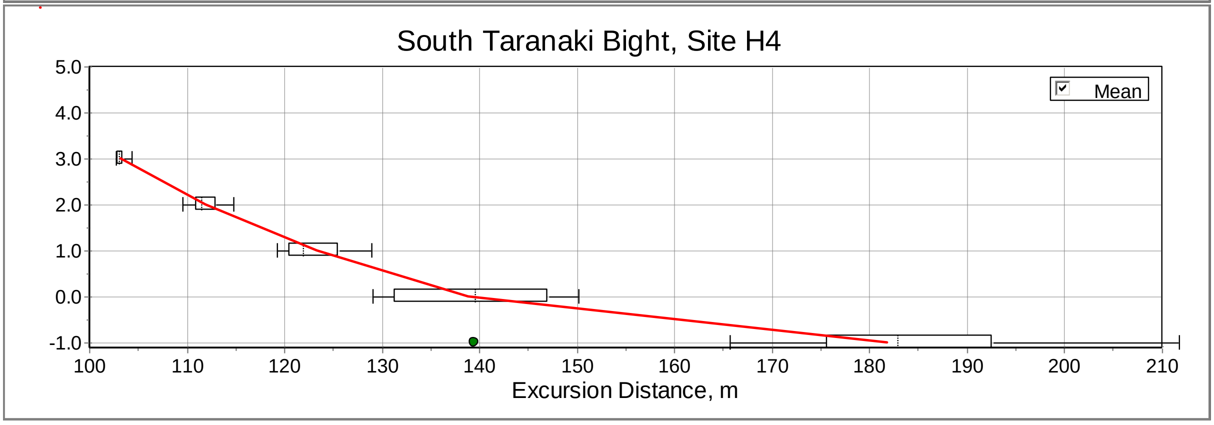


Ohawe - excursion distance plots

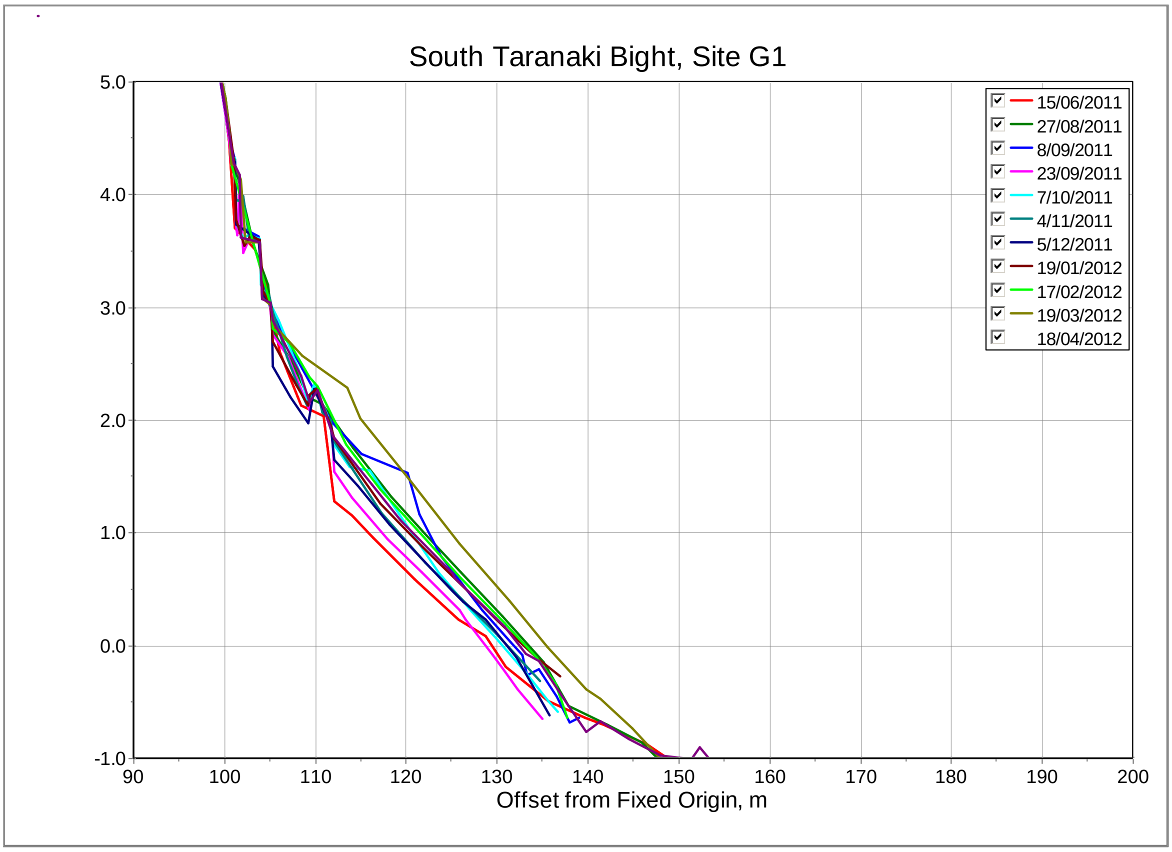


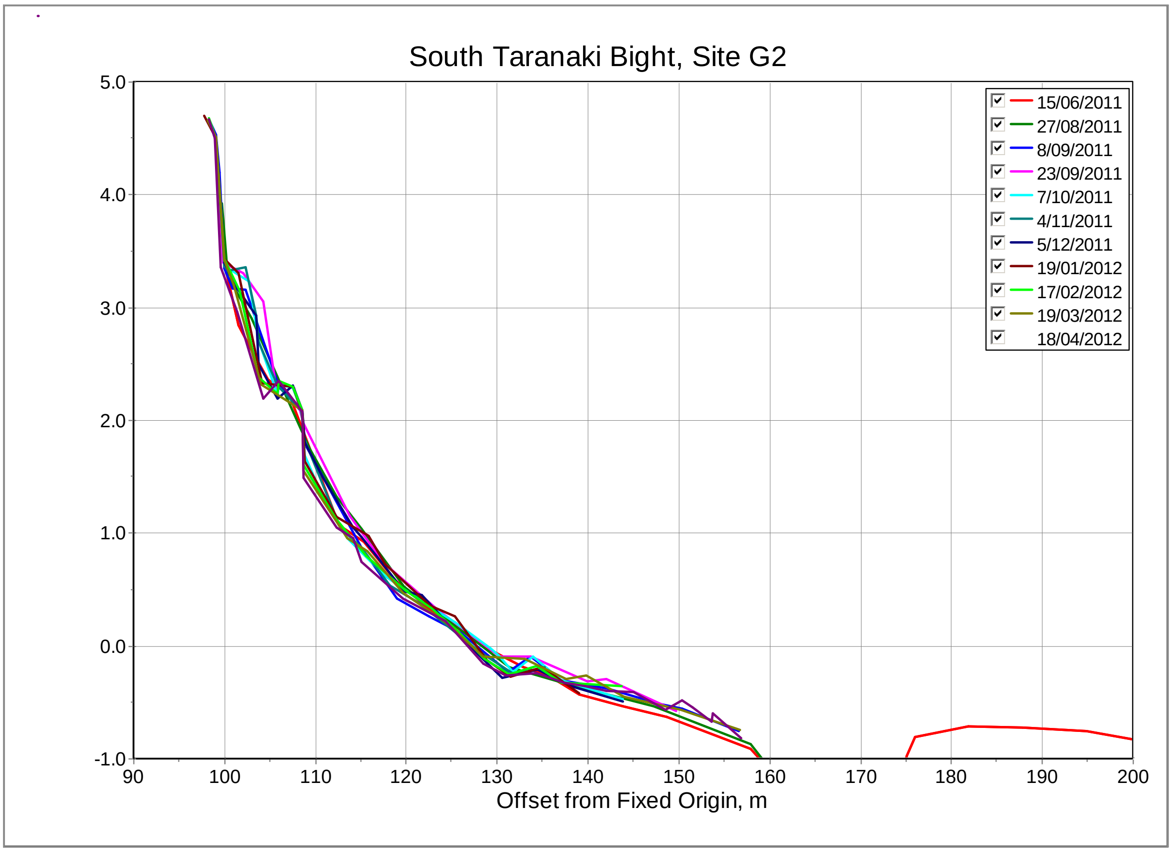


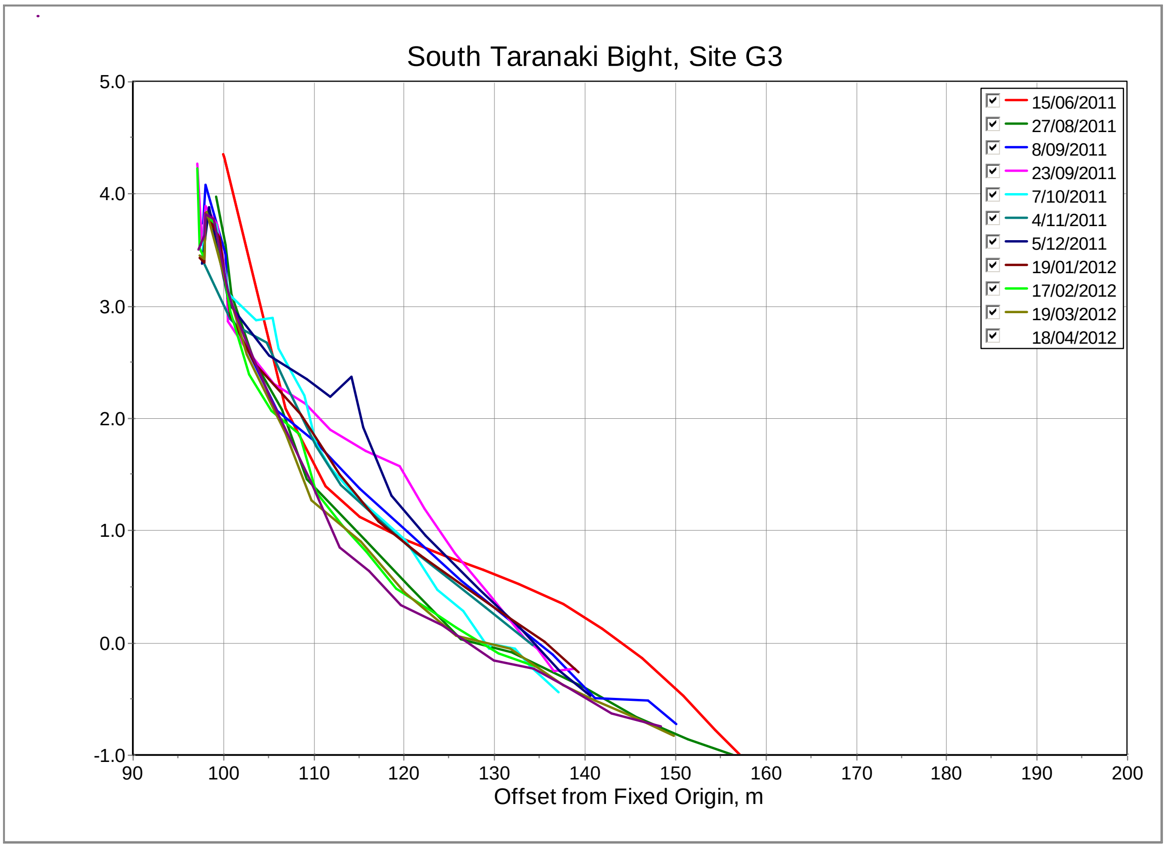




Hawera- Site G - beach profile plots



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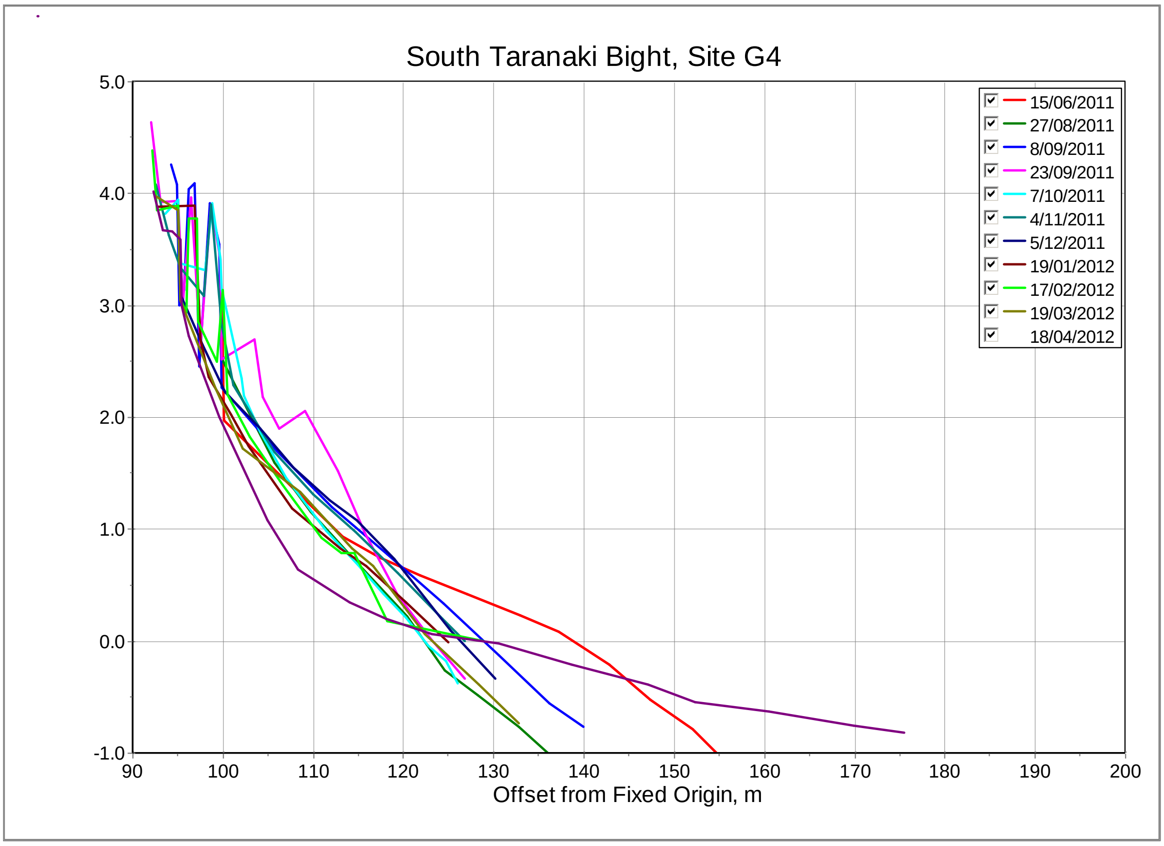
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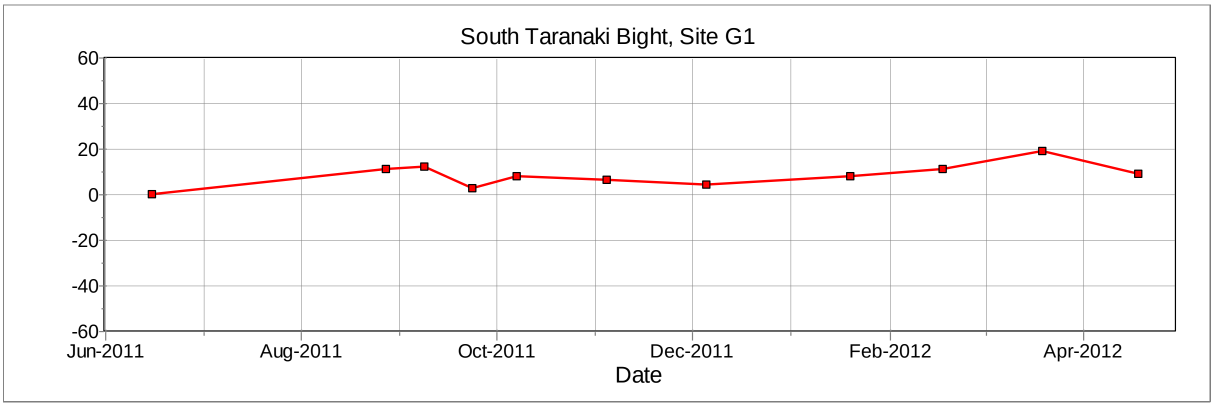
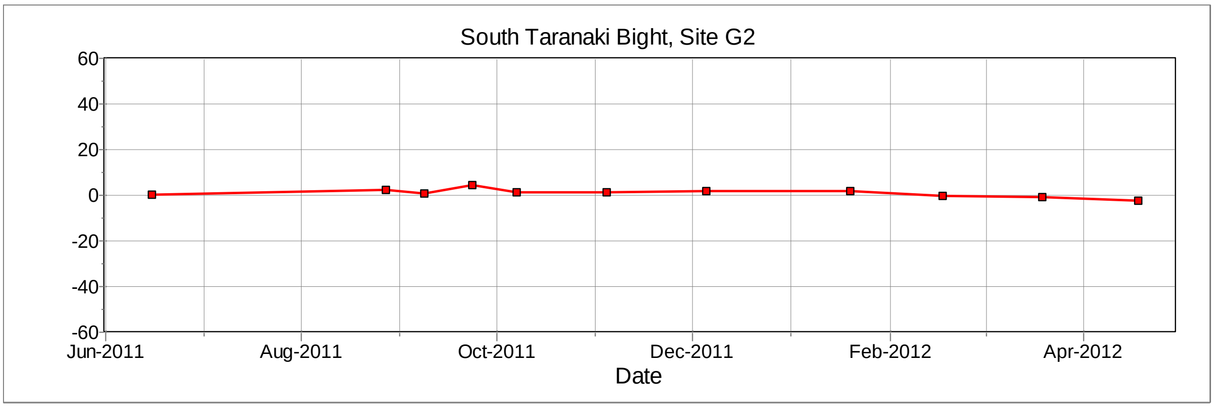
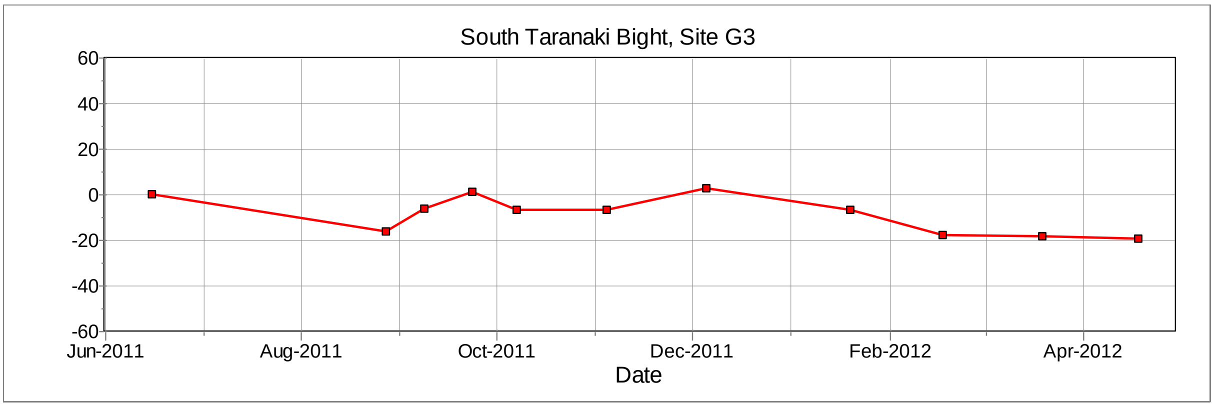
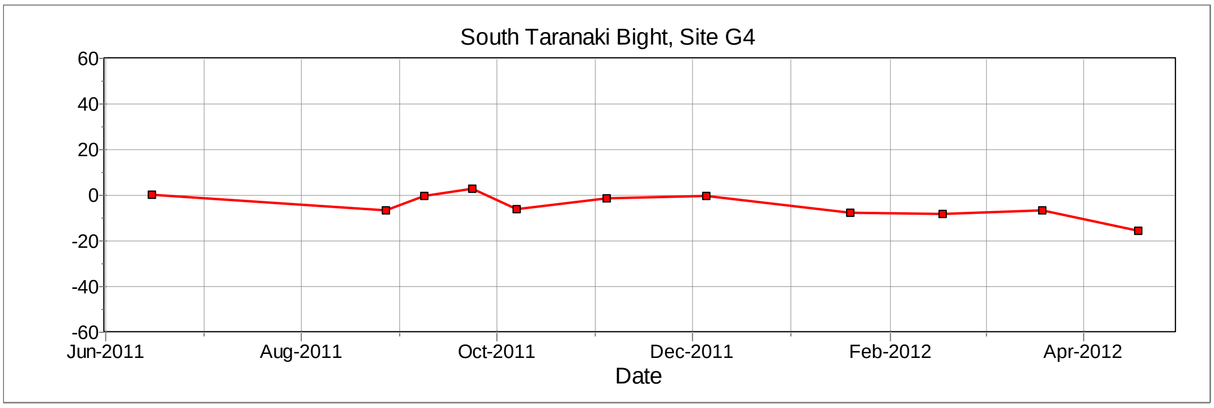
Hawera - beach volume change (cut/fill) plots

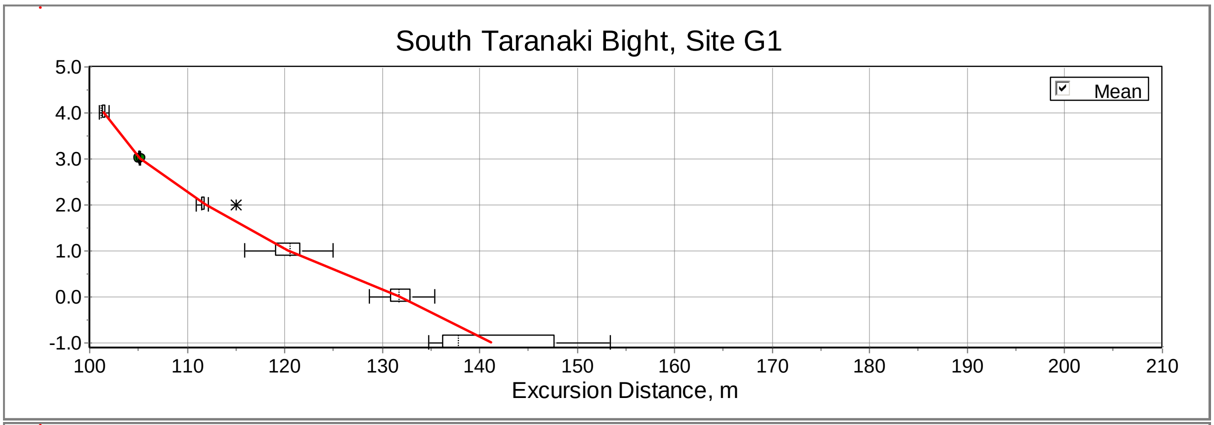


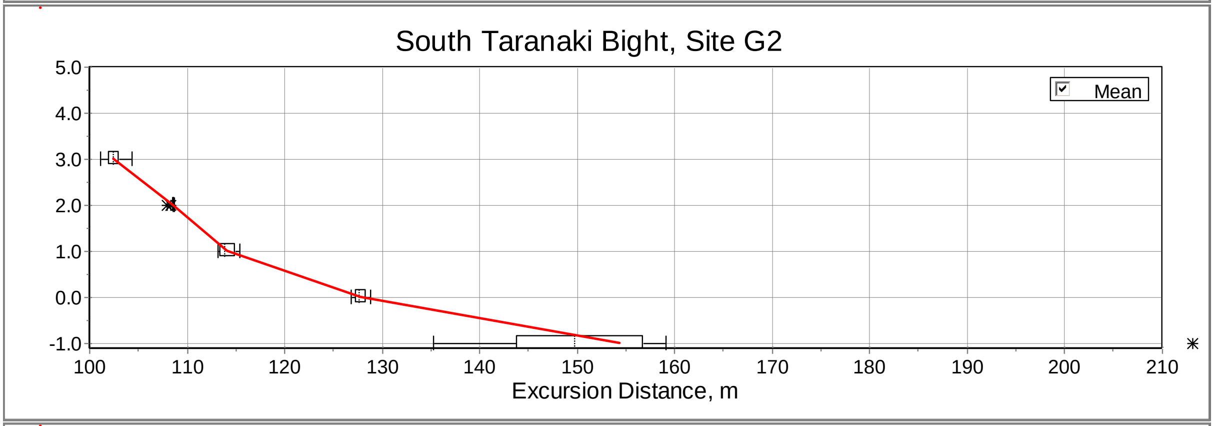


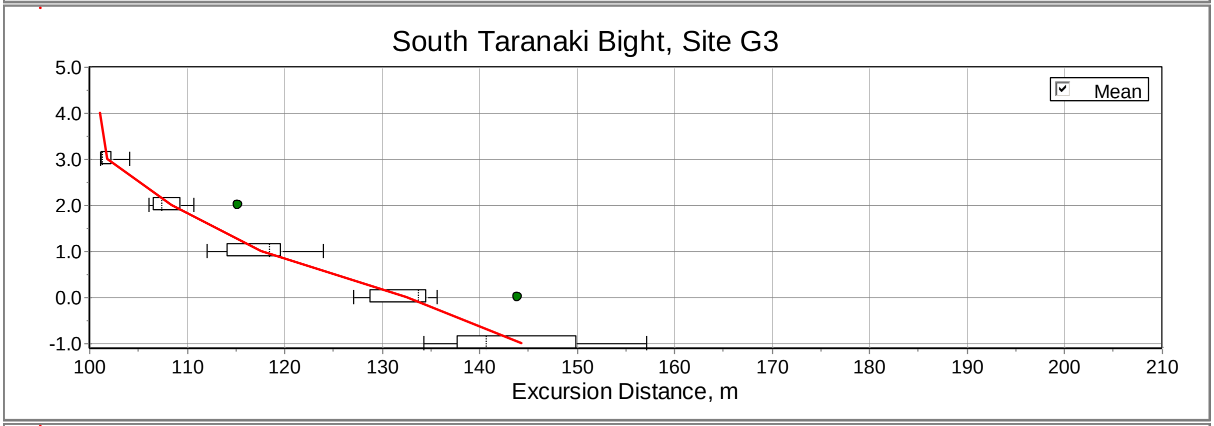


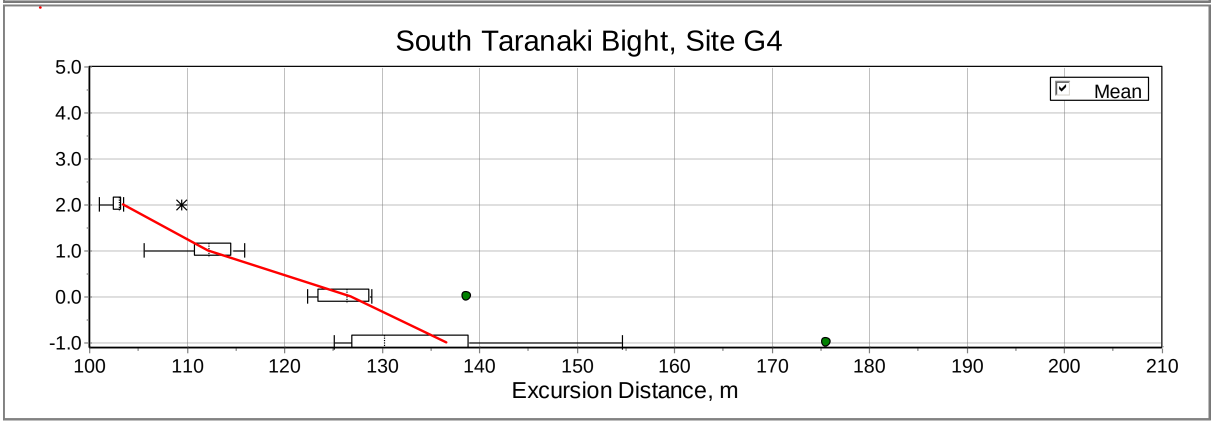


Hawera - excursion distance plots

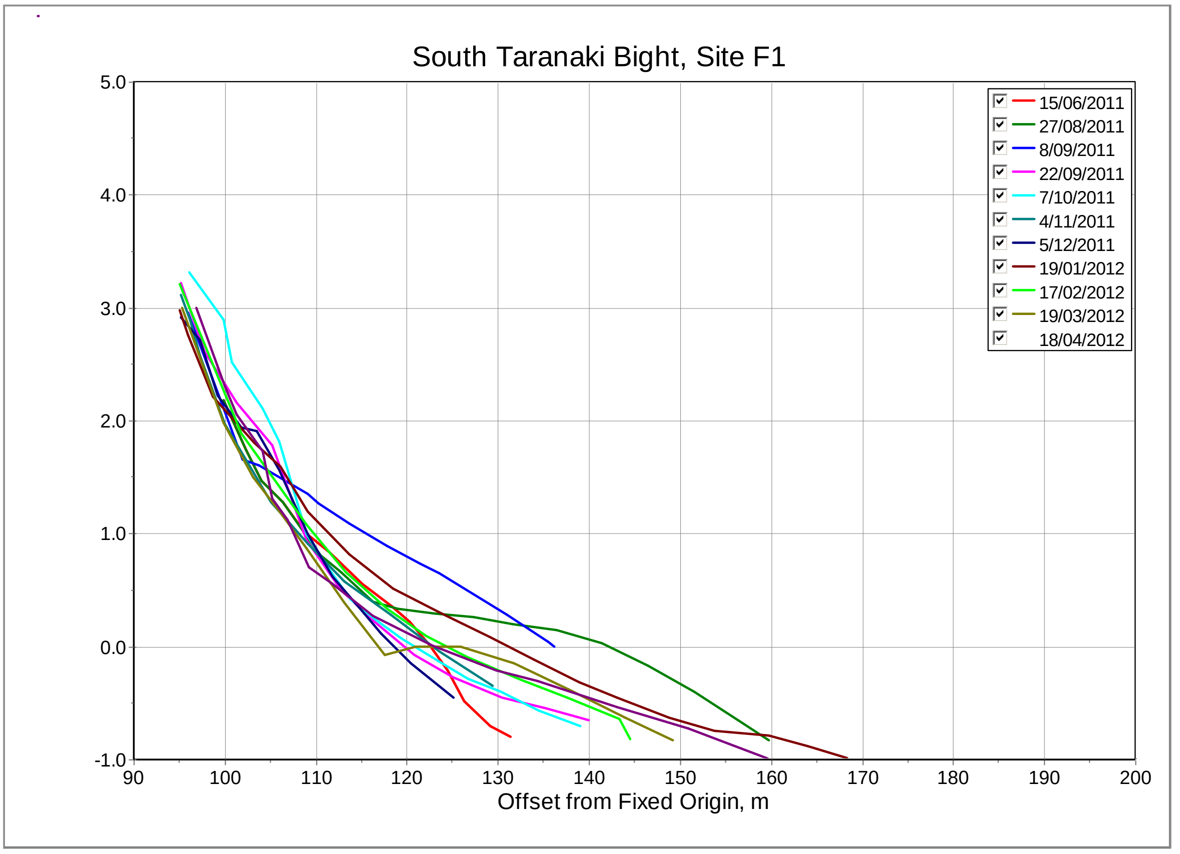


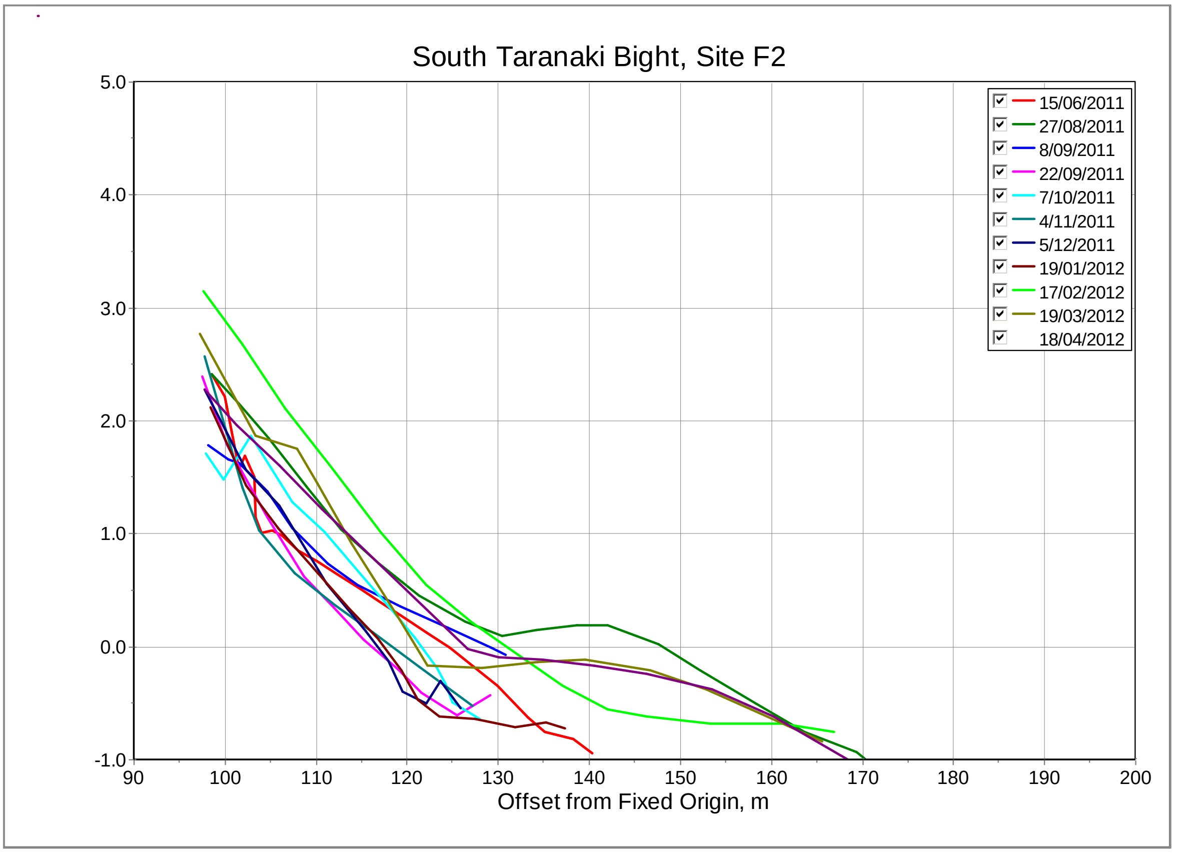


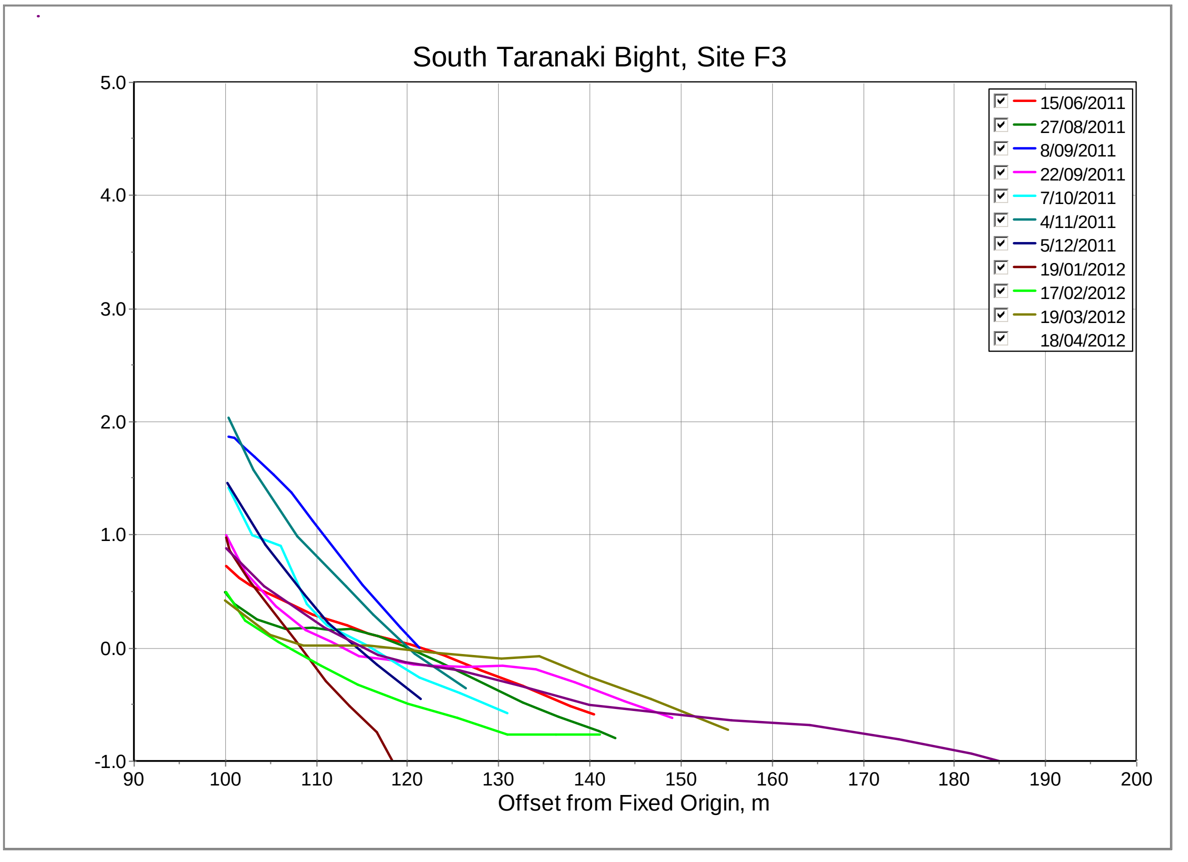




Manawapou – Site F - beach profile plots



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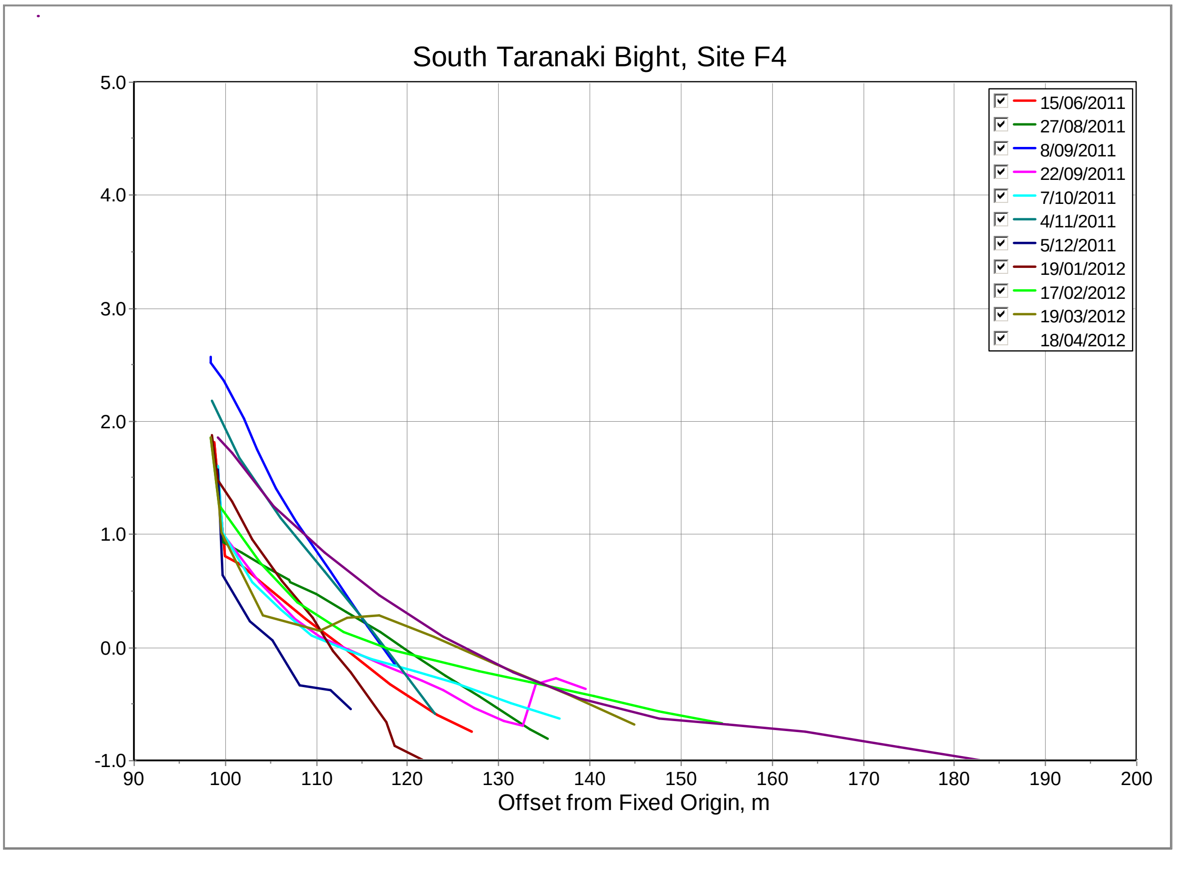
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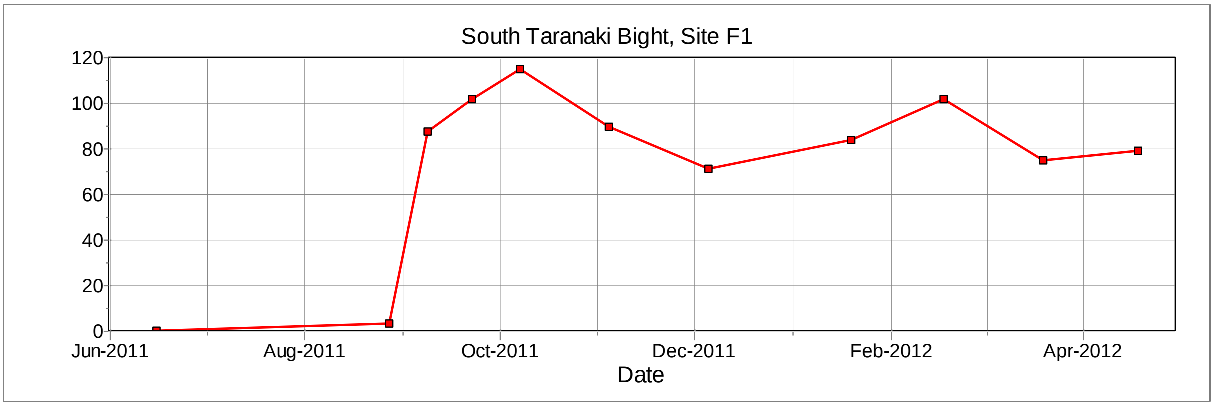
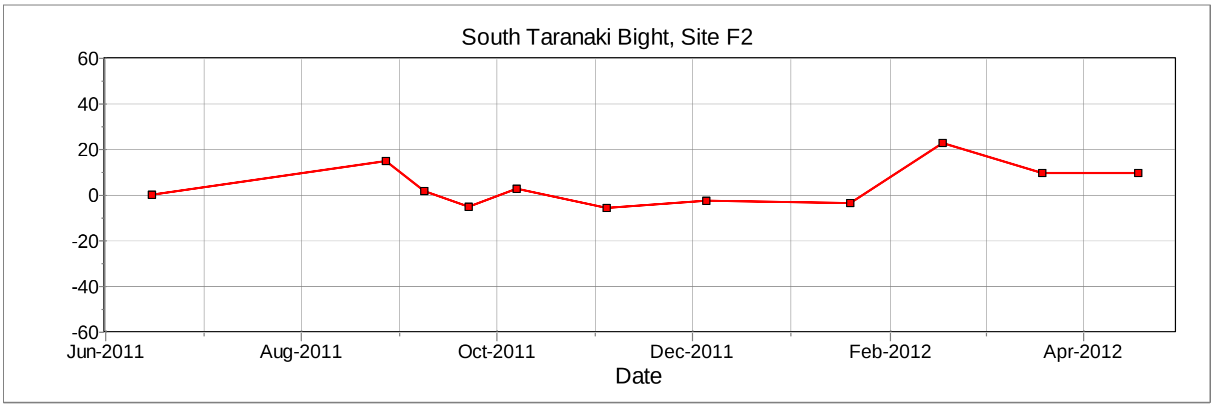
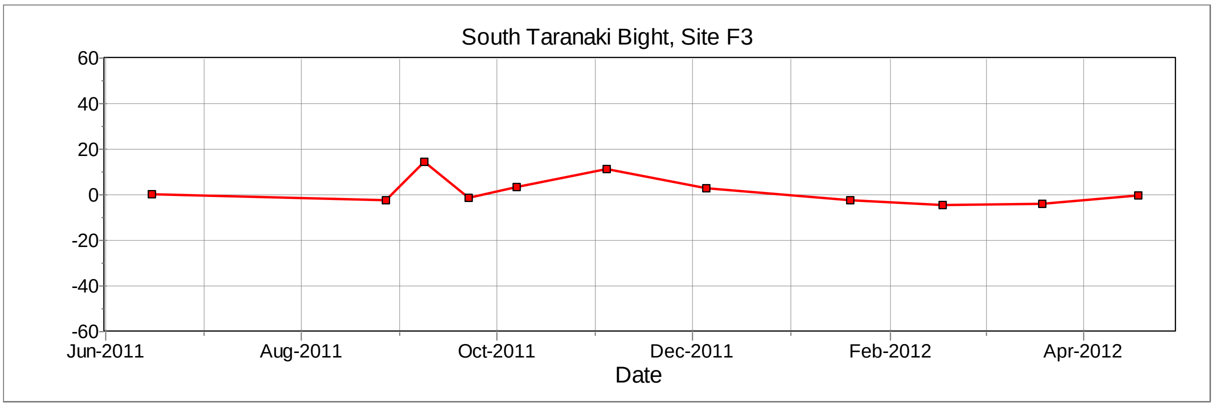
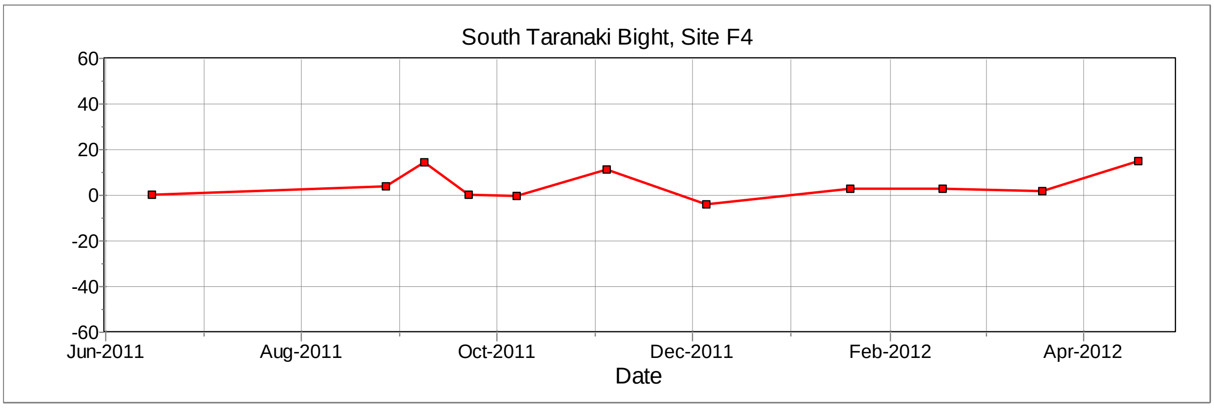
Manawapou - beach volume change (cut/fill) plots

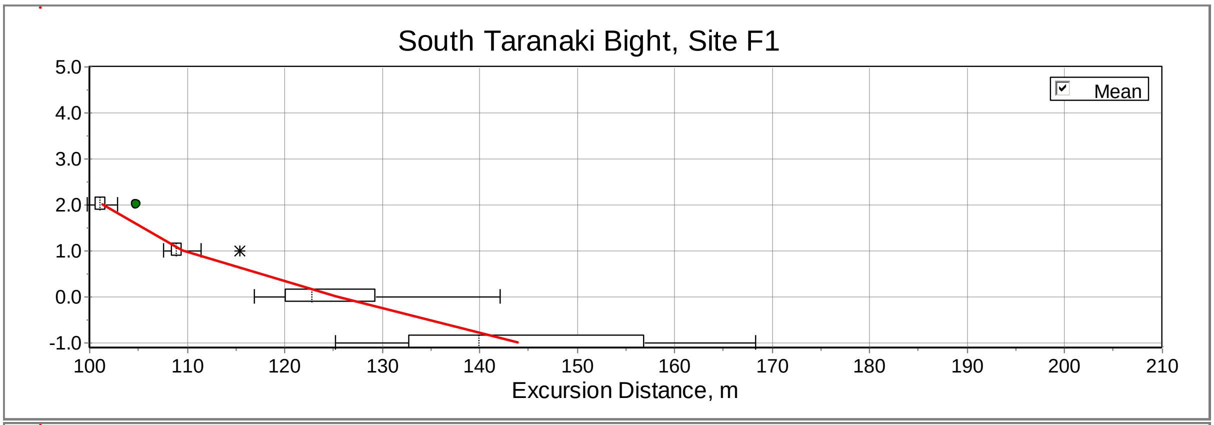


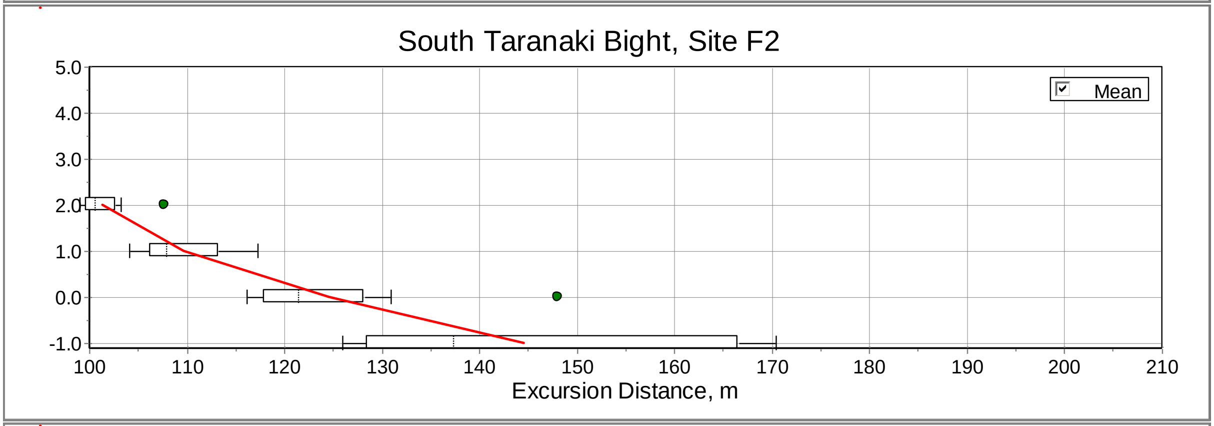


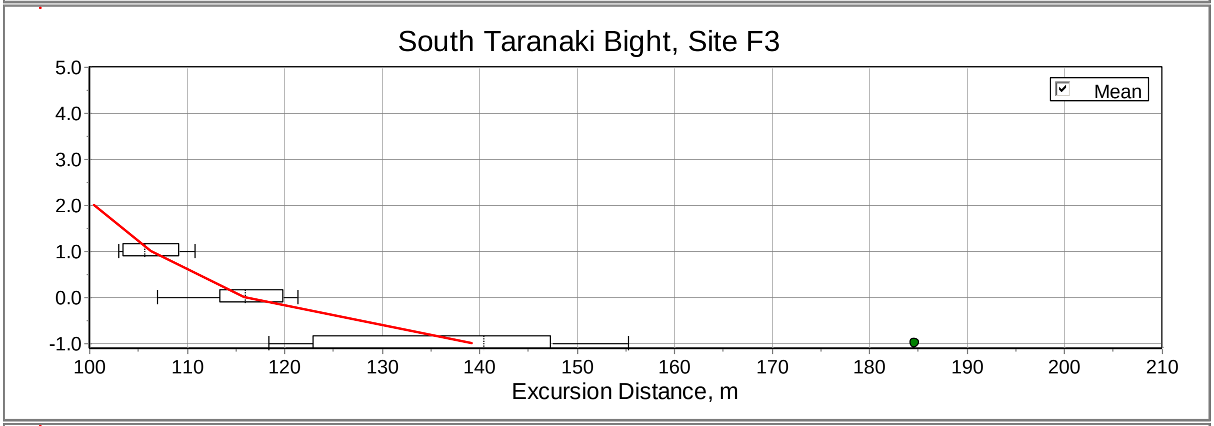


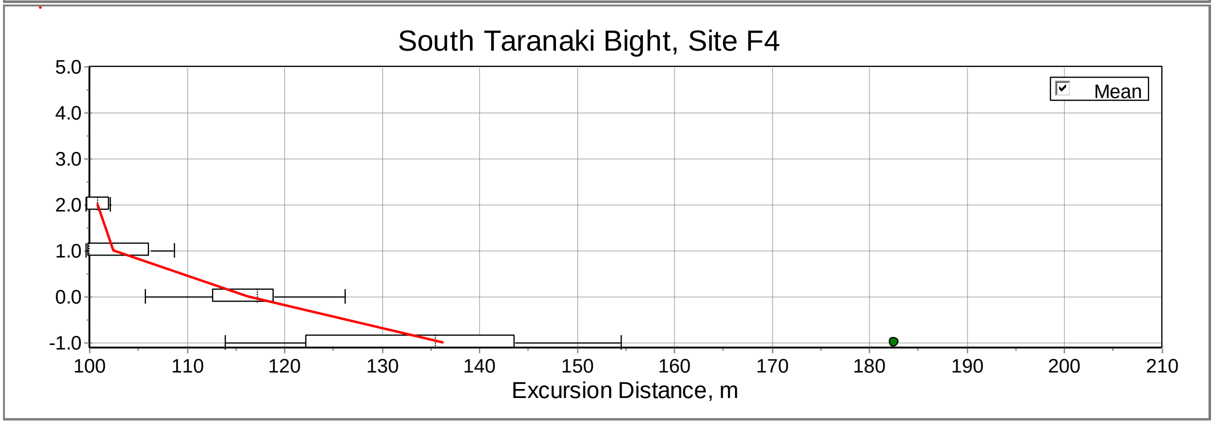


Manawapou - excursion distance plots

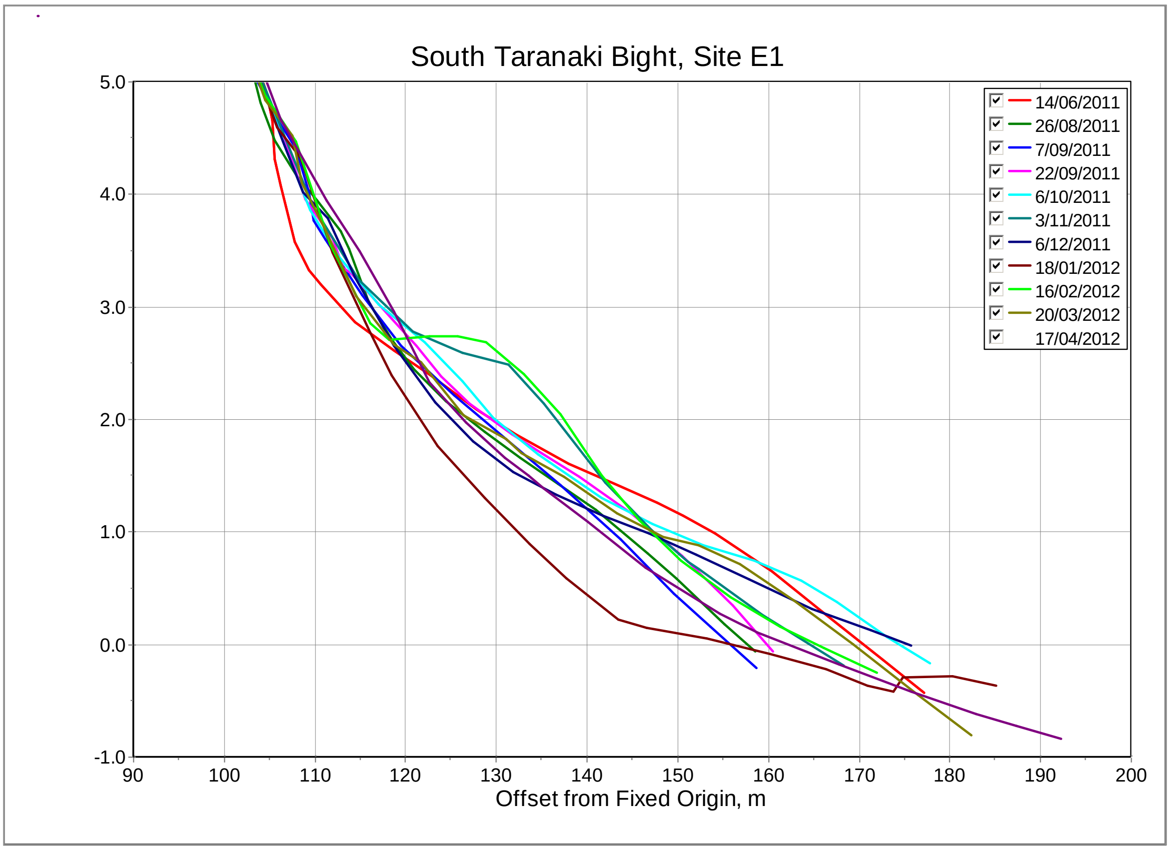


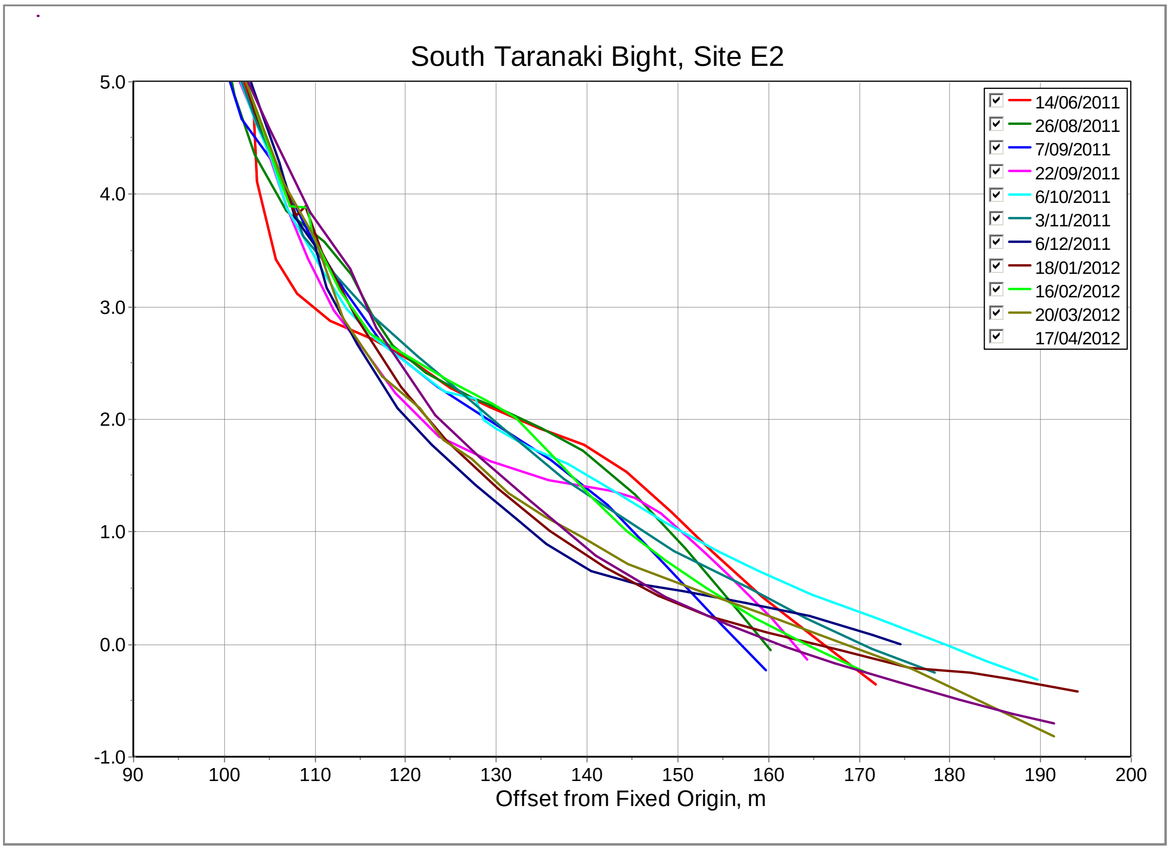


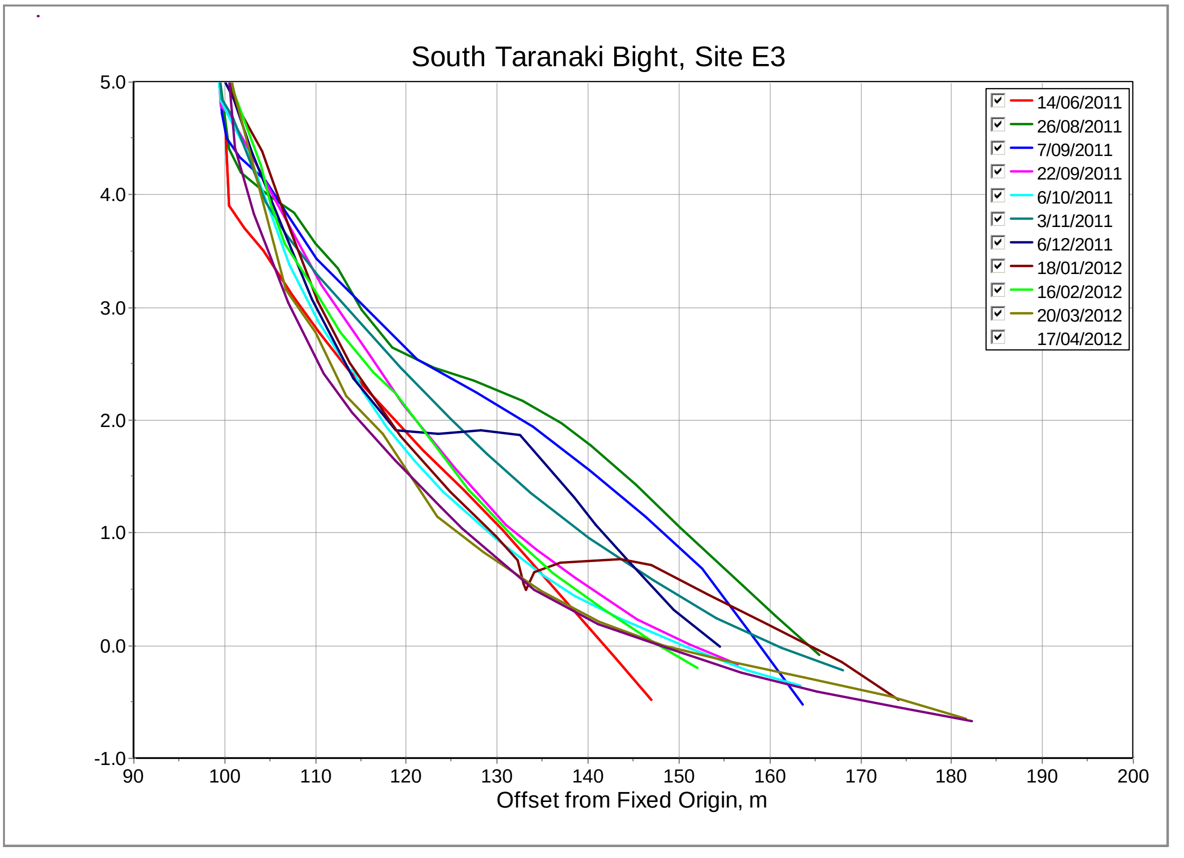




Patea – Site E - beach profile plots



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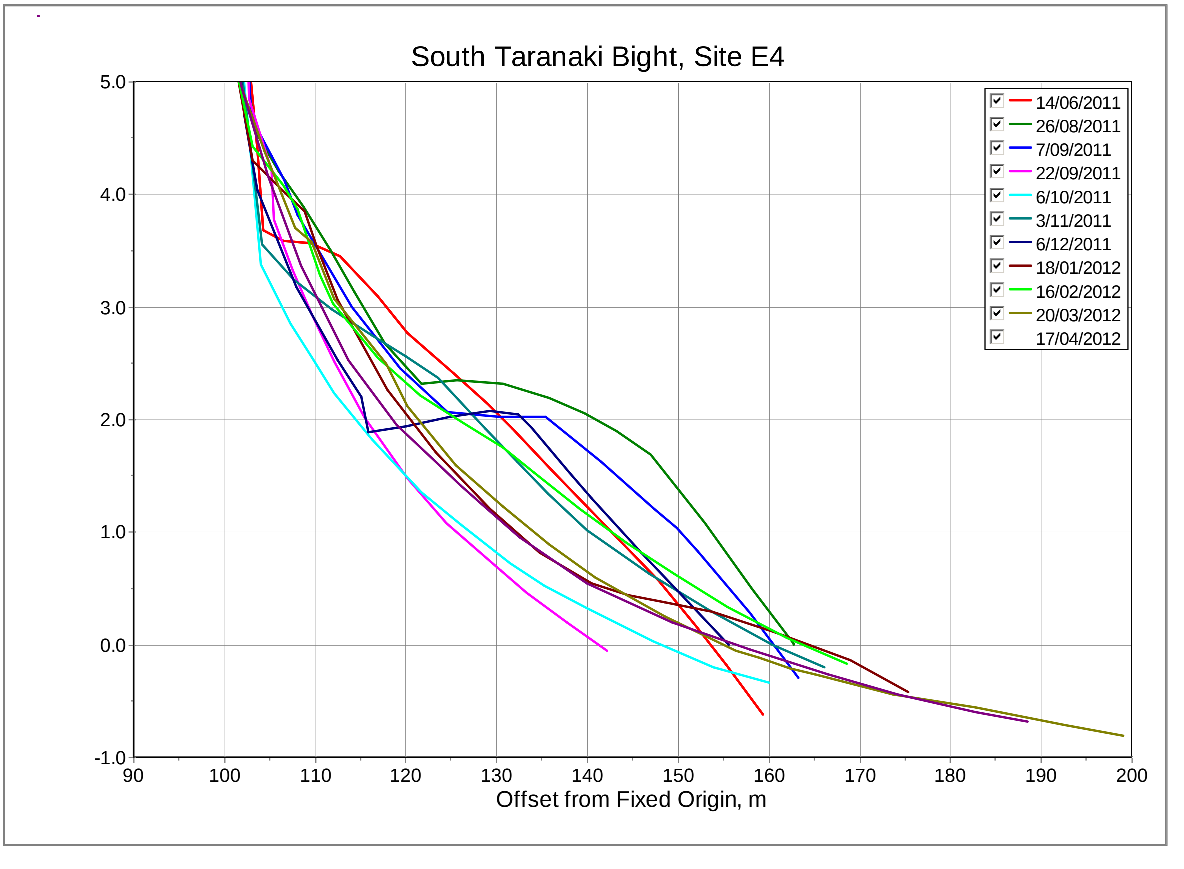
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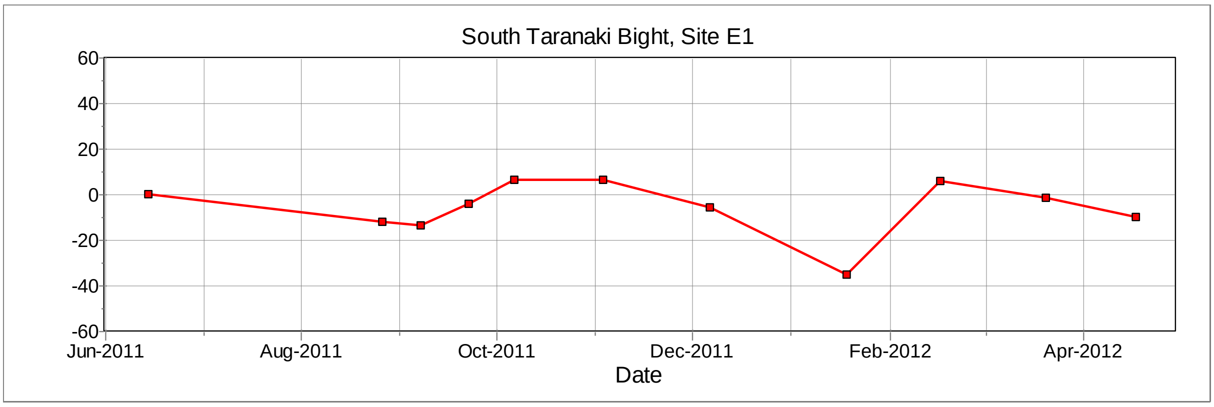
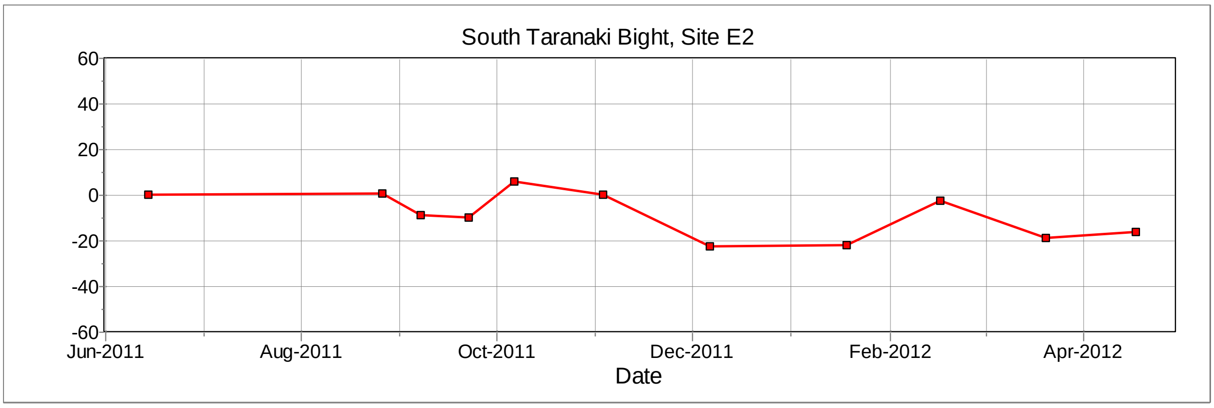
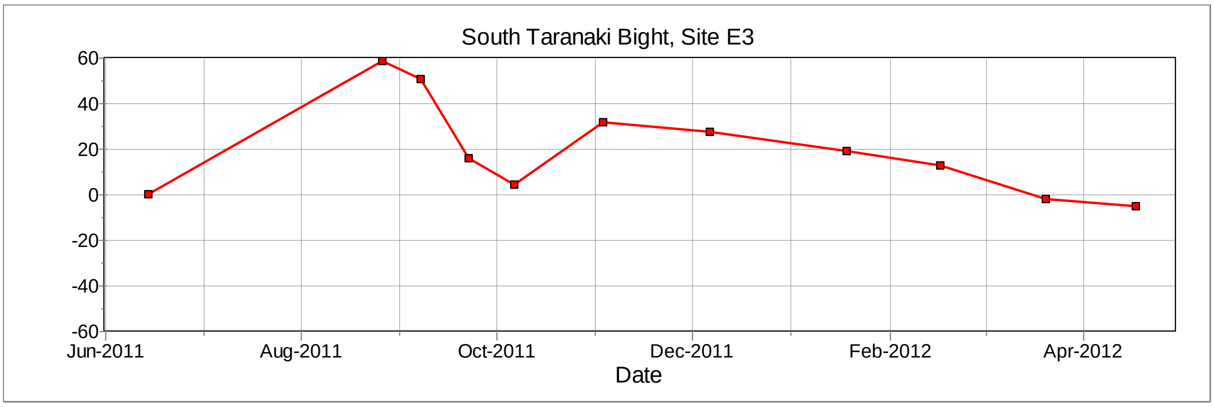
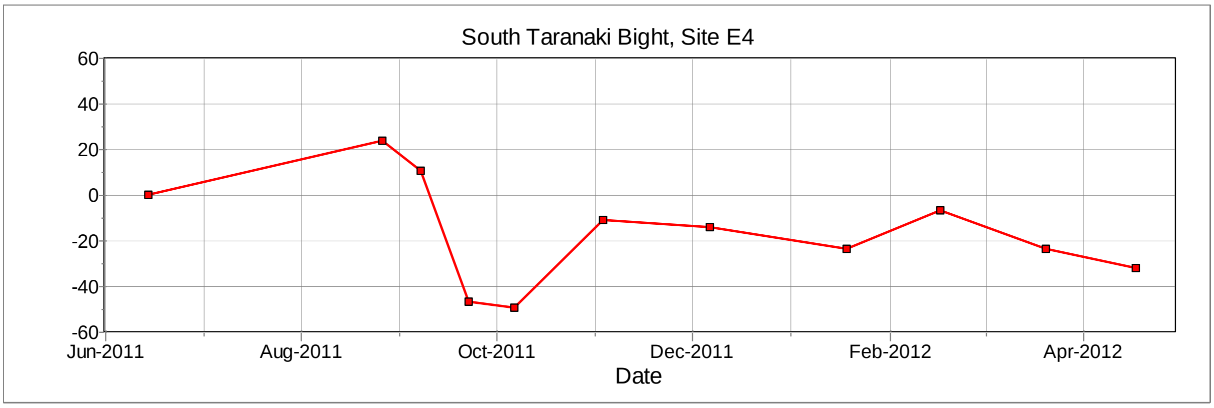
20/03/2012
17/04/2012

Patea - beach volume change (cut/fill) plots

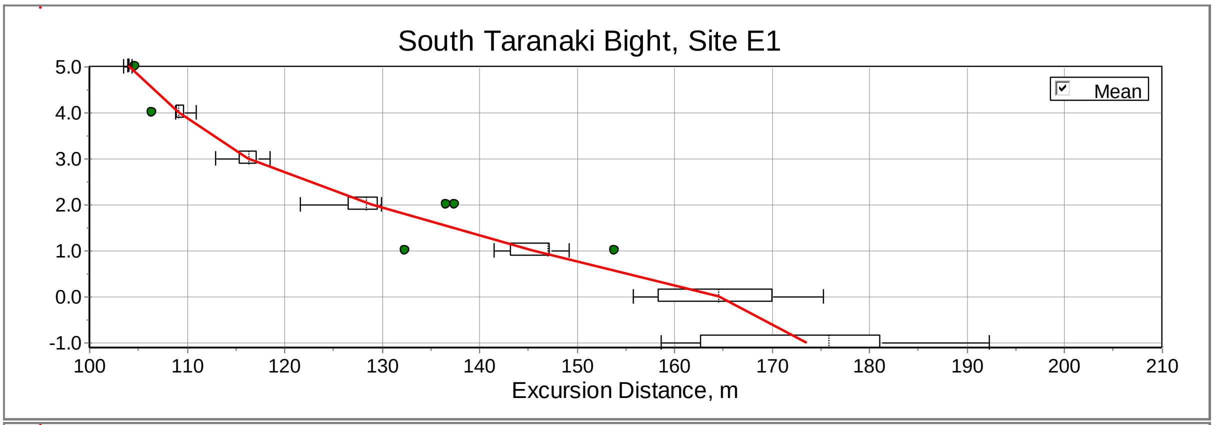


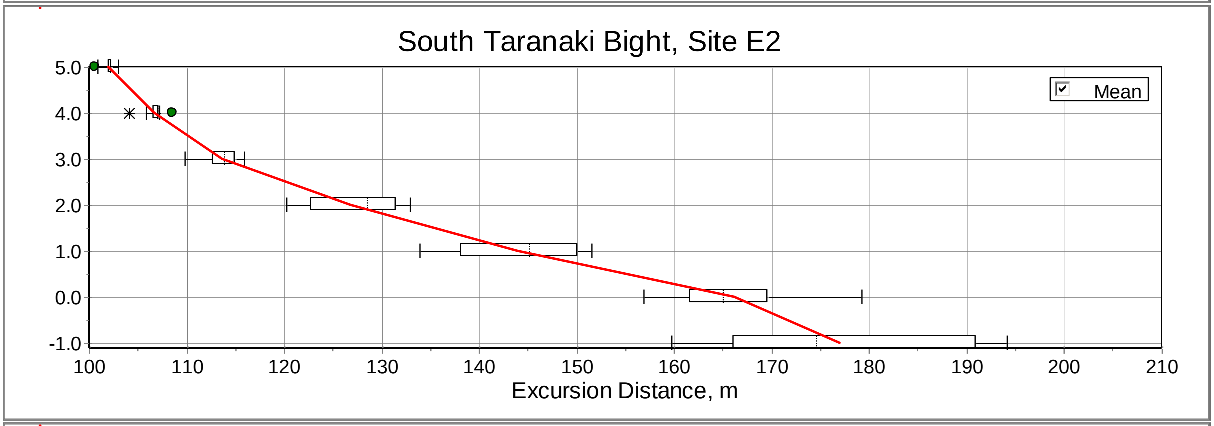


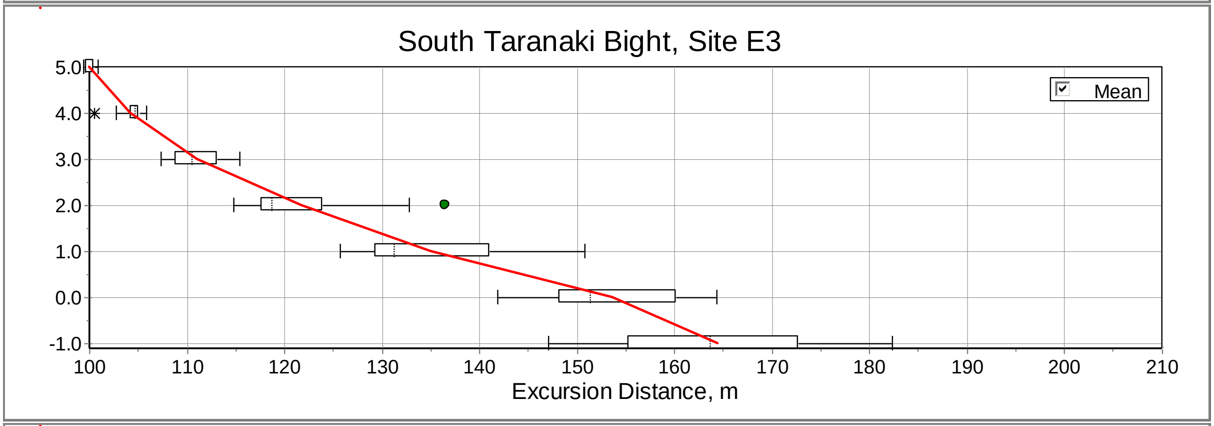


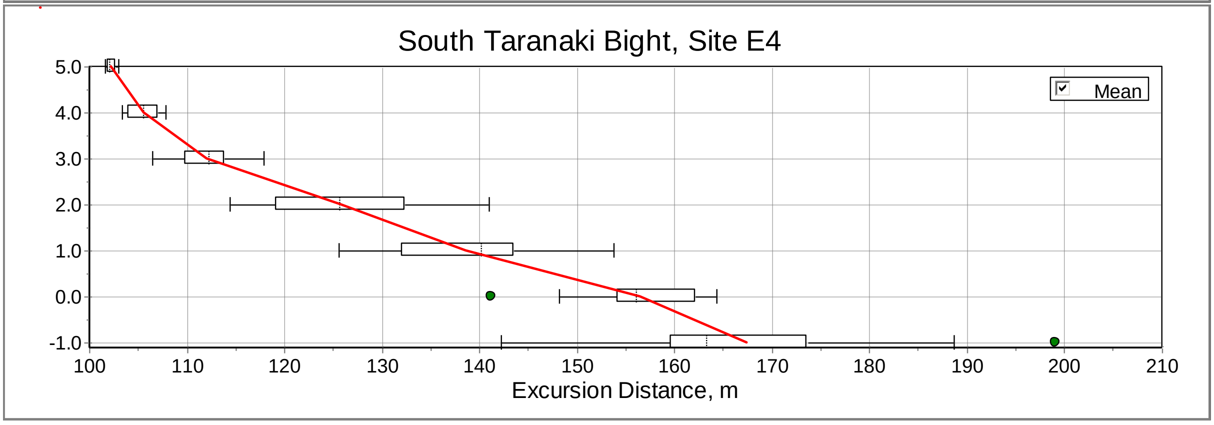


Patea - excursion distance plots

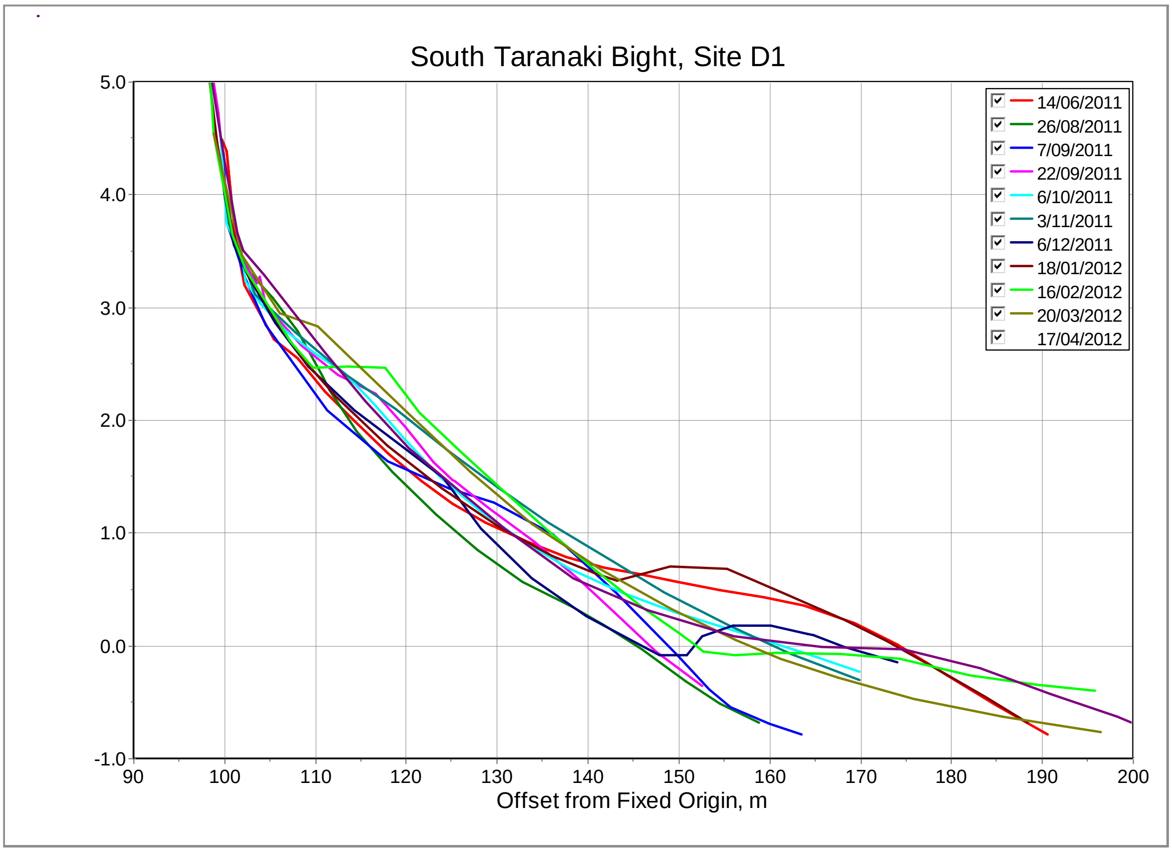


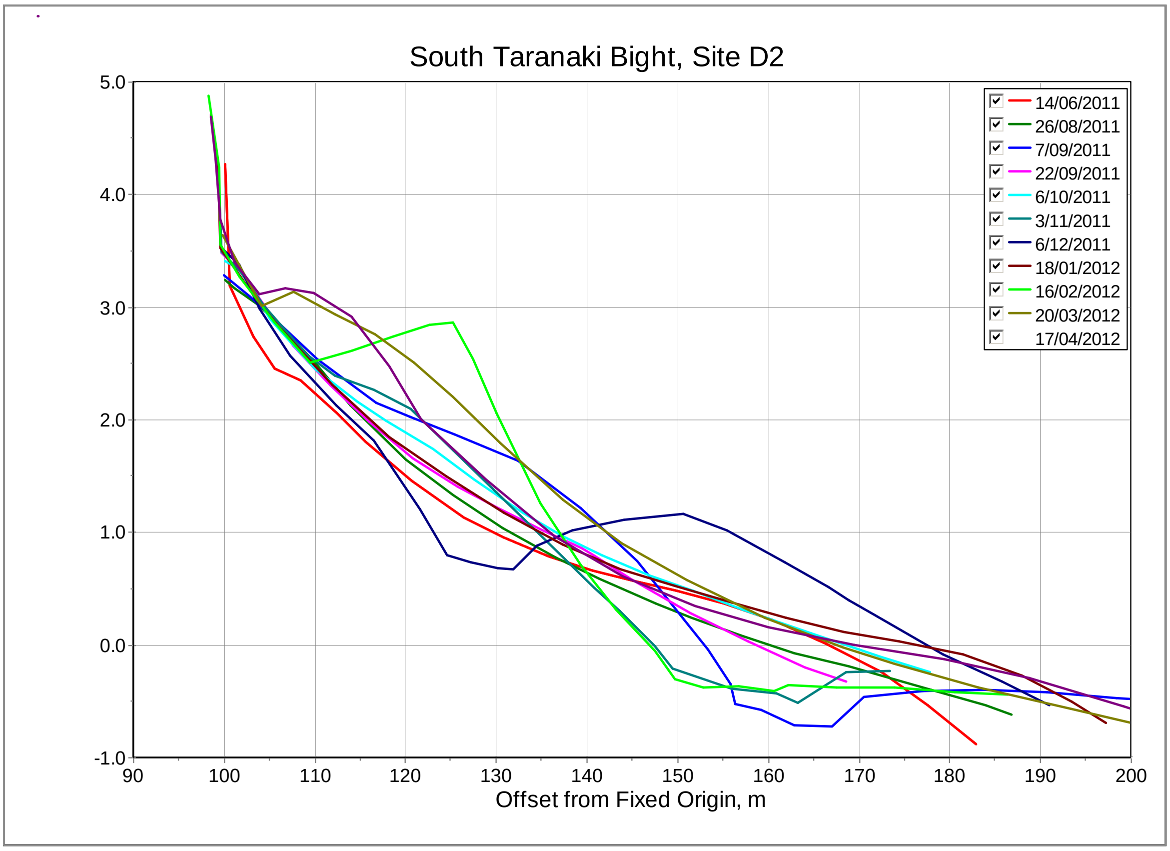


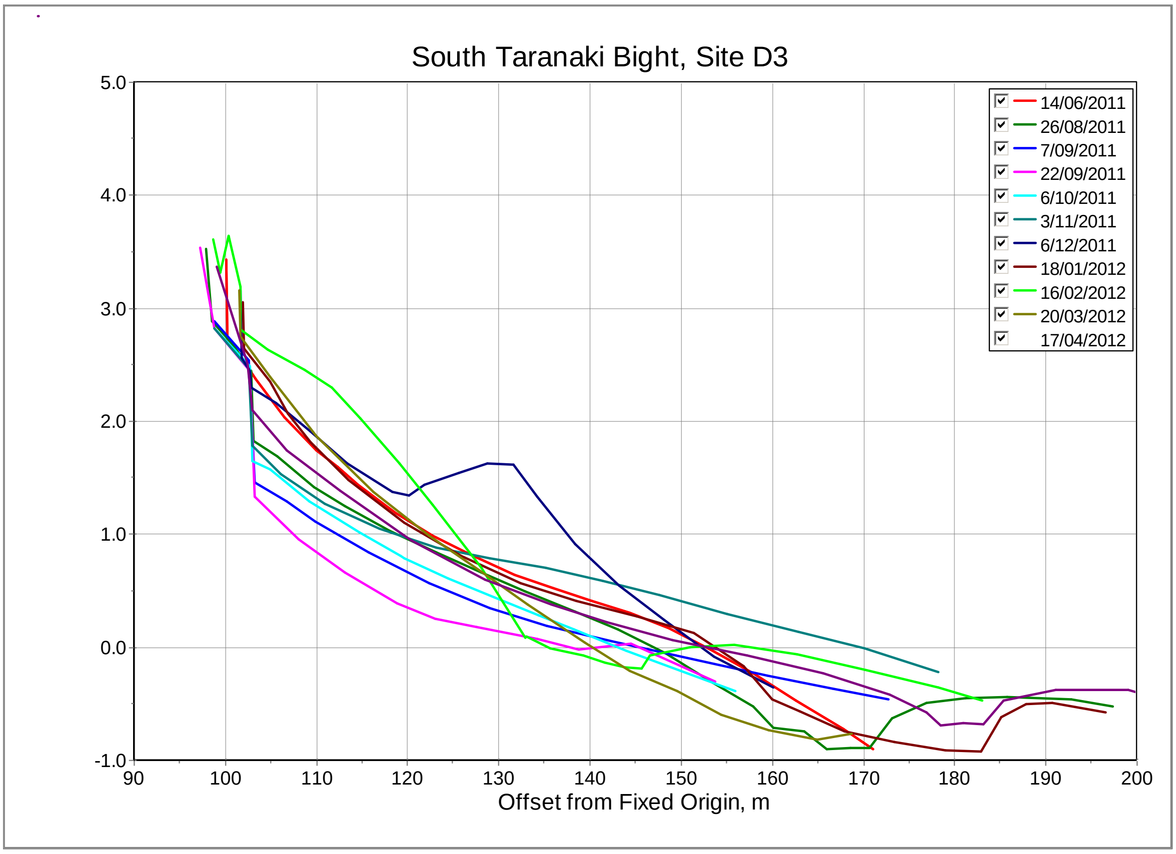




Waverley – Site D - beach profile plots



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0.0
-1.0
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140
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180
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Offset from Fixed Origin, m
14/06/2011
26/08/2011
7/09/2011
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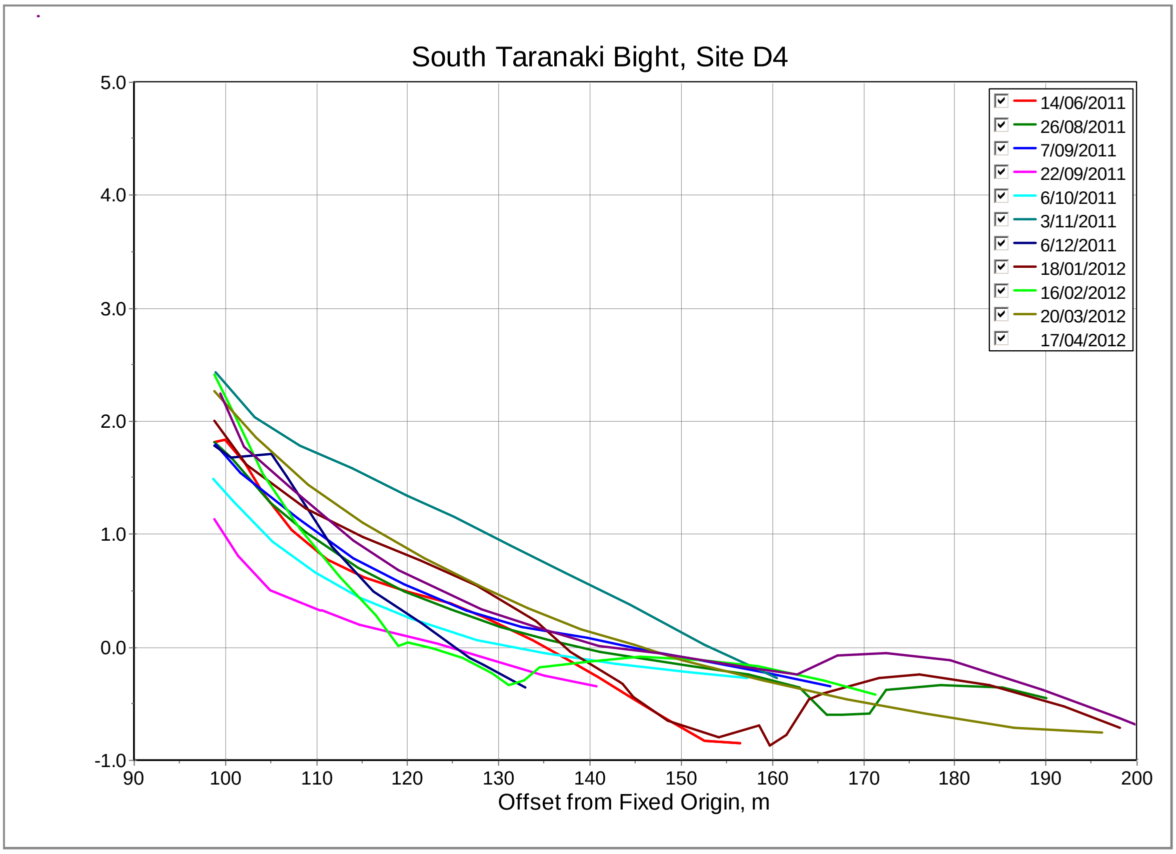
20/03/2012
17/04/2012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Offset from Fixed Origin, m
14/06/2011
26/08/2011
7/09/2011
22/09/2011
6/10/2011
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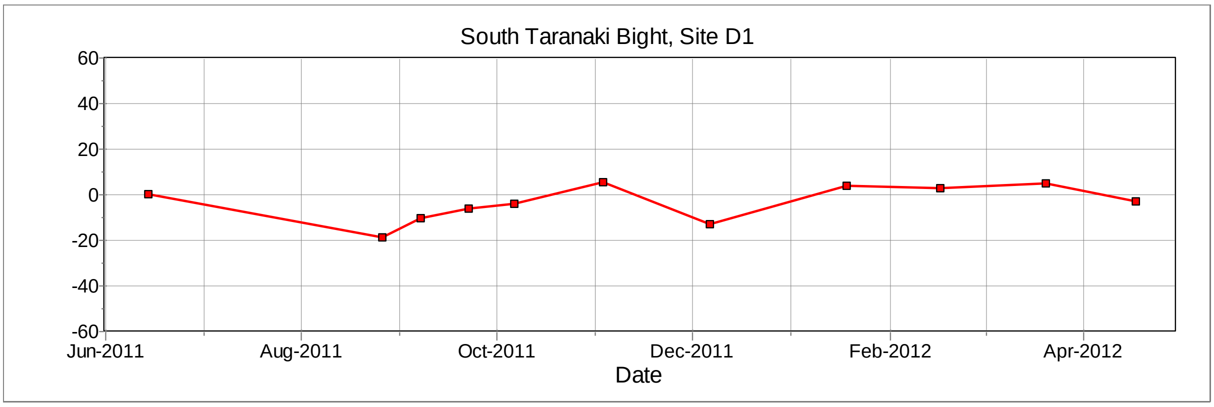
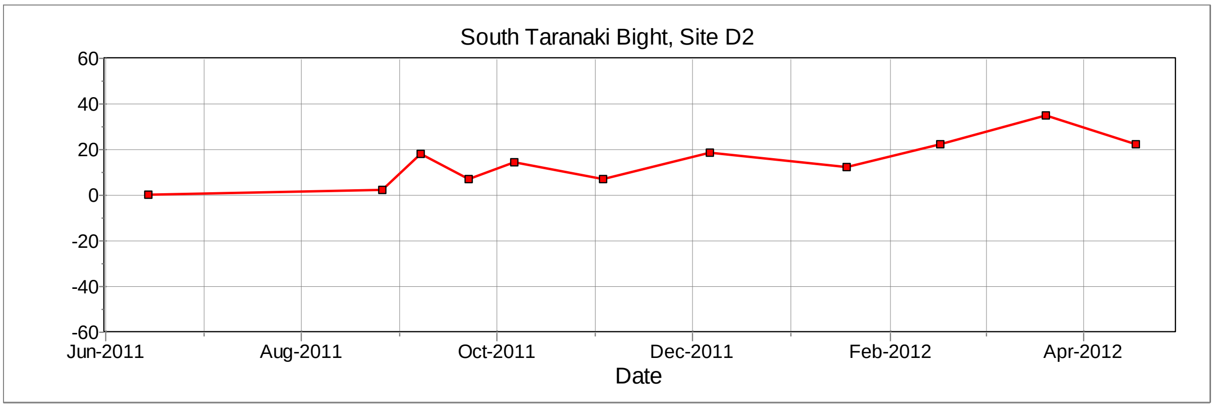
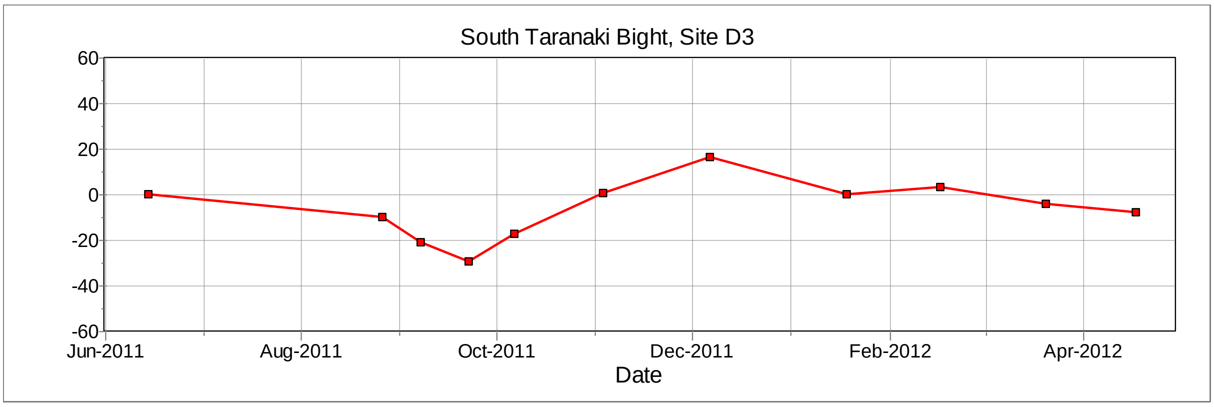
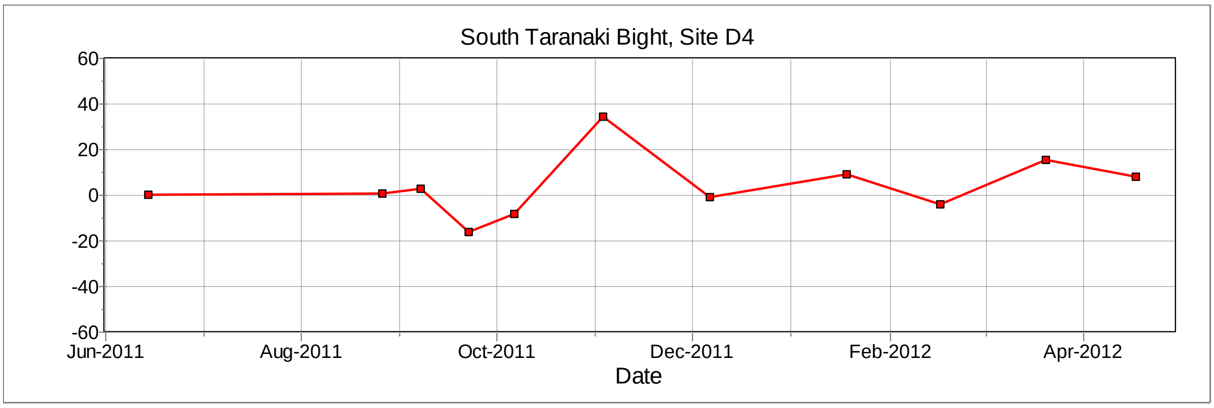
16/02/2012
20/03/2012
17/04/2012

Waverley - beach volume change (cut/fill) plots

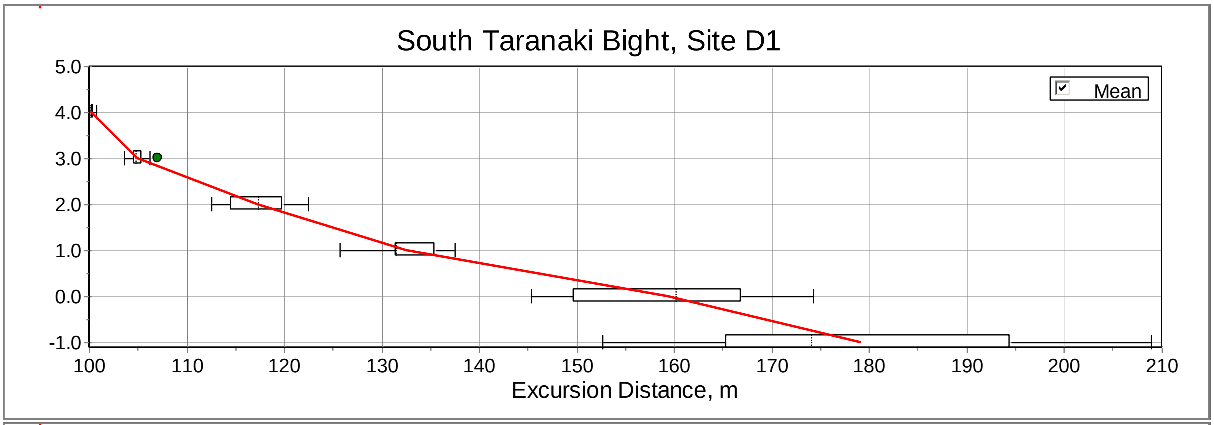


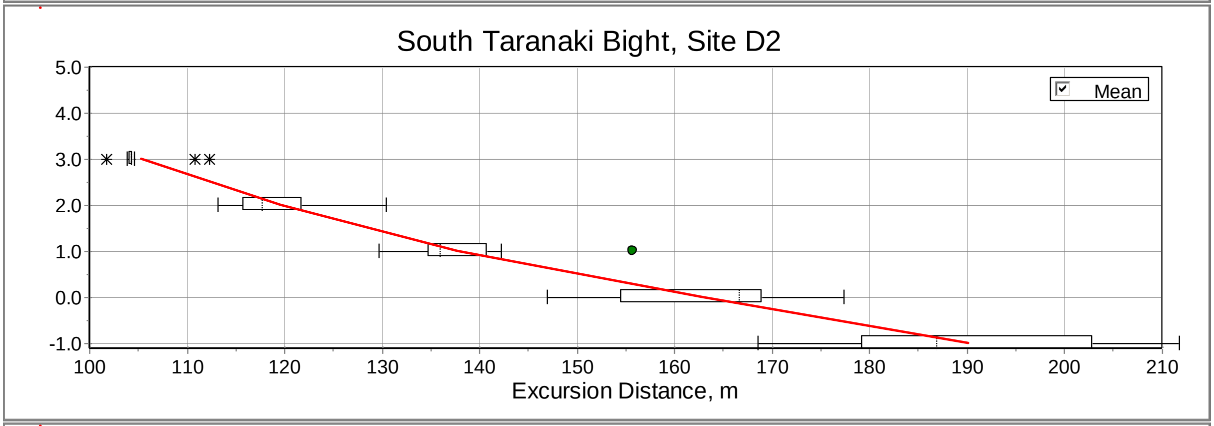


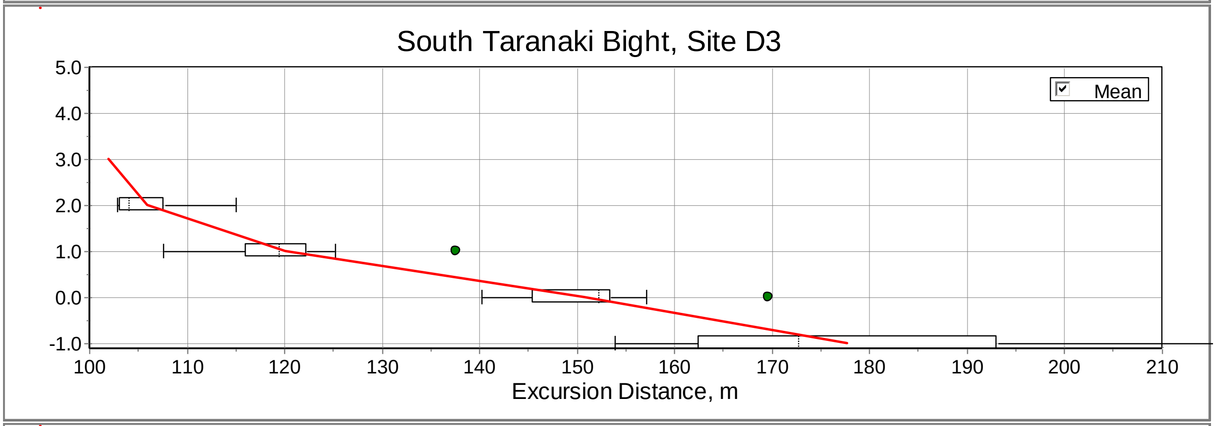


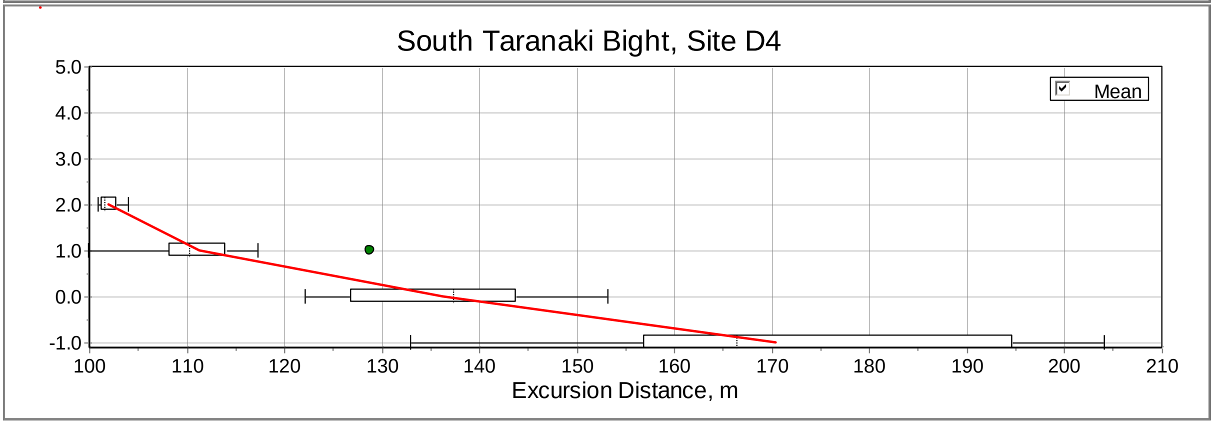


Waverley - excursion distance plots

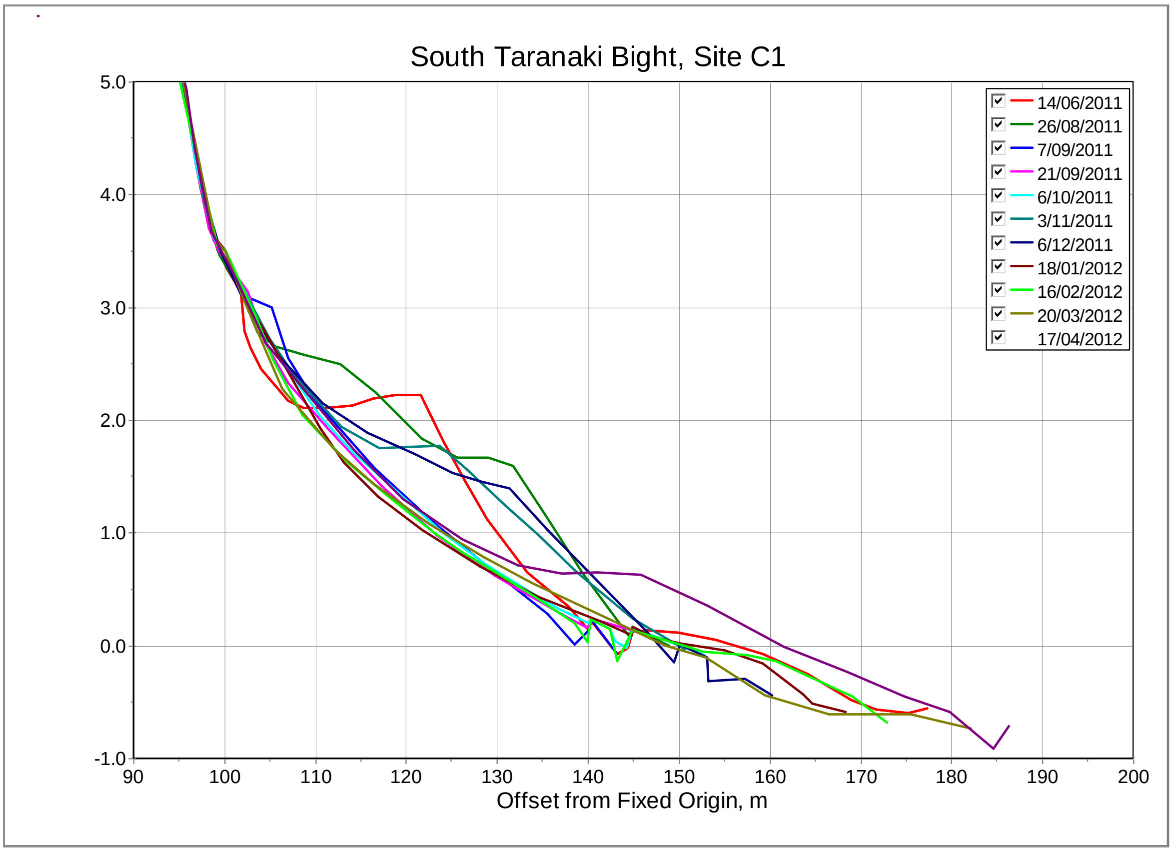


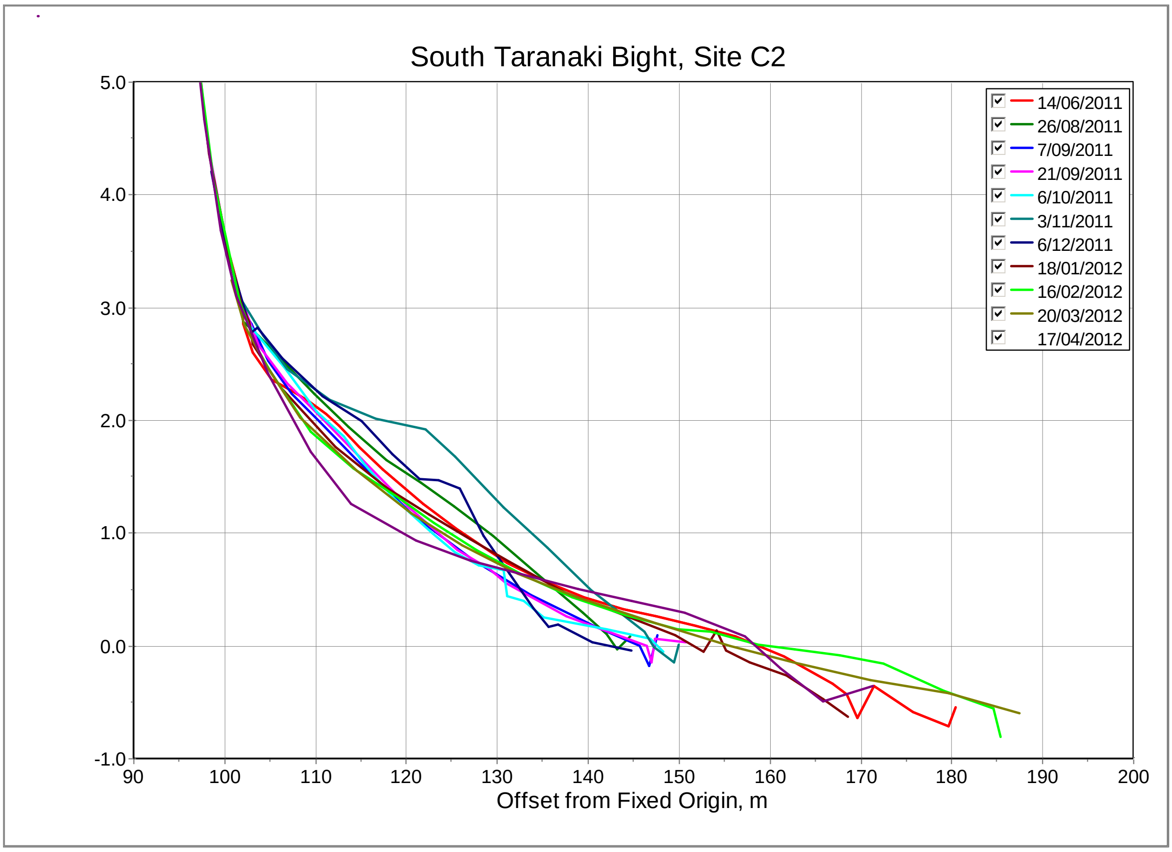


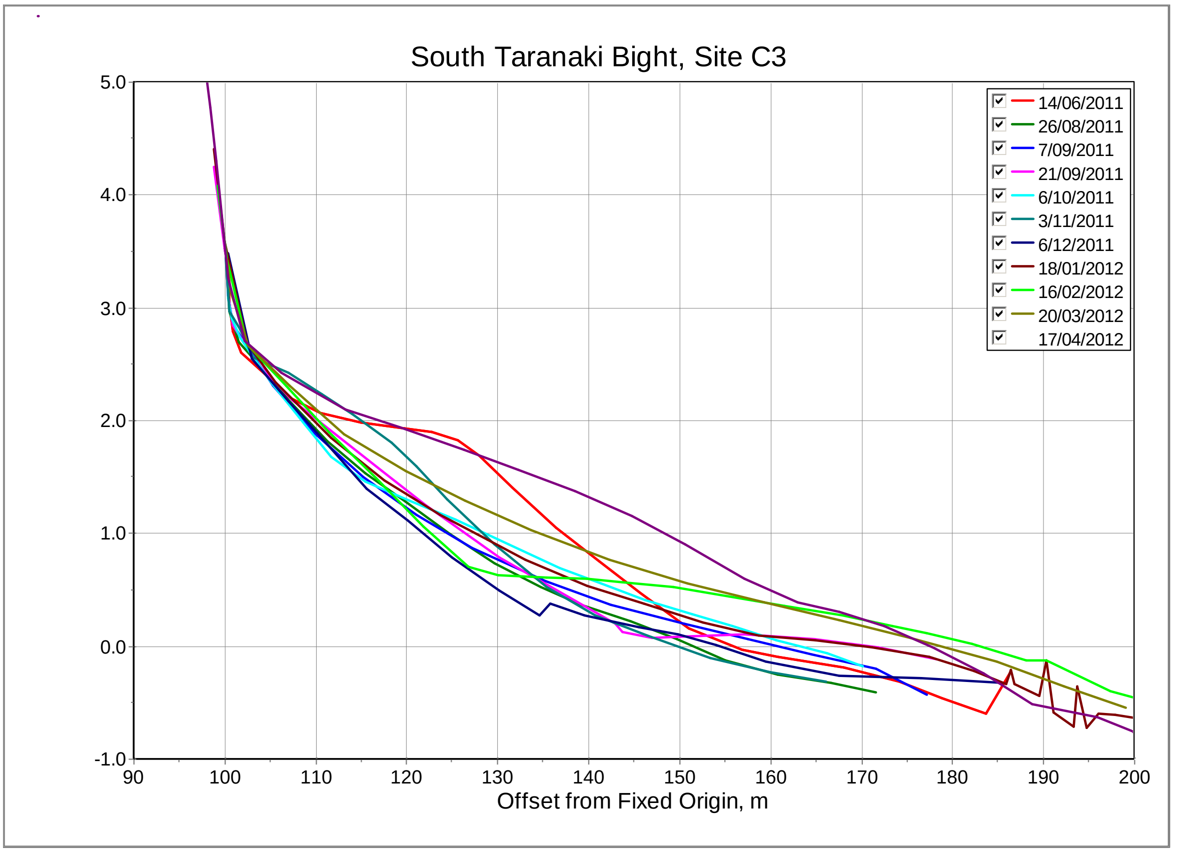




Waiinu – Site C - beach profile plots







South Taranaki Bight, Site C3
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
90
100
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120
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140
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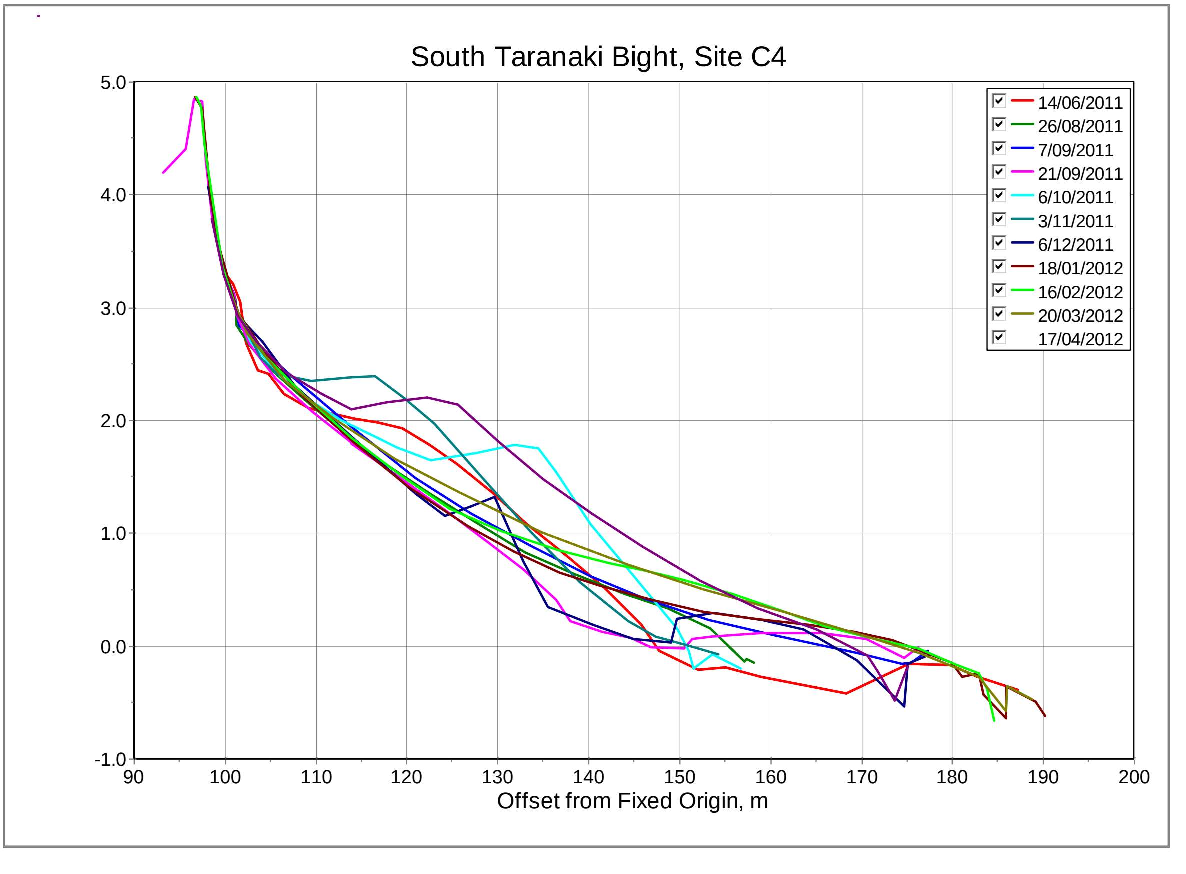
200
Offset from Fixed Origin, m
14/06/2011
26/08/2011
7/09/2011
21/09/2011
6/10/2011
3/11/2011
6/12/2011
18/01/2012
16/02/2012
20/03/2012
17/04/2012



South Taranaki Bight, Site C4
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4.0
3.0
2.0
1.0
0.0
-1.0
90
100
110
120
130
140
150
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Offset from Fixed Origin, m
14/06/2011
26/08/2011
7/09/2011
21/09/2011
6/10/2011
3/11/2011
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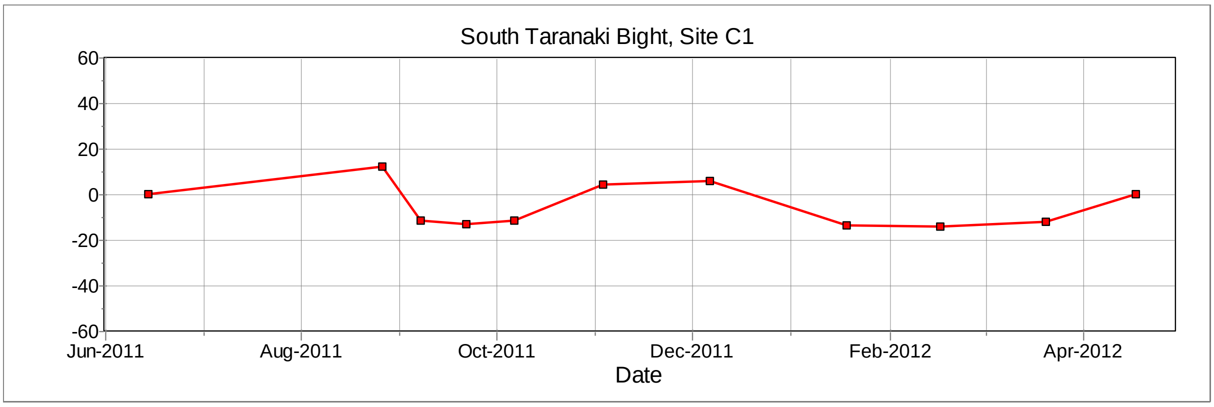
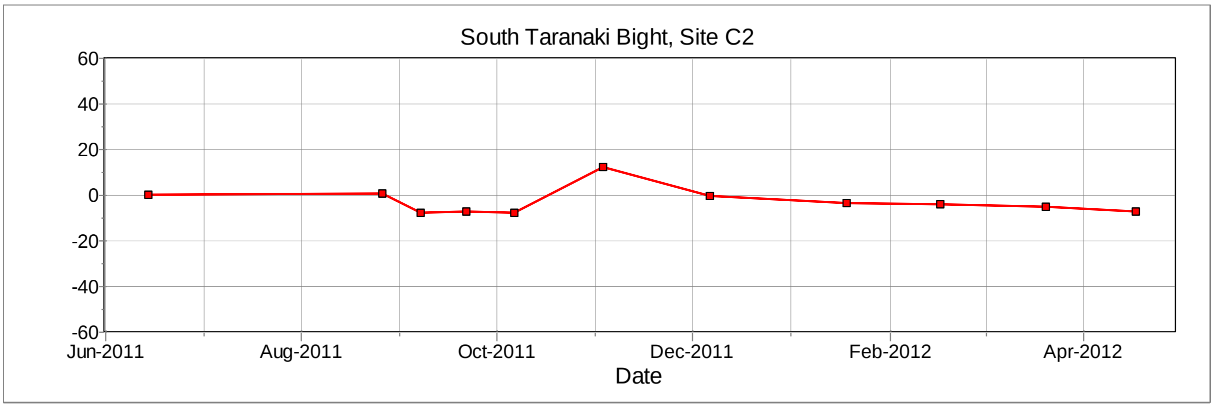
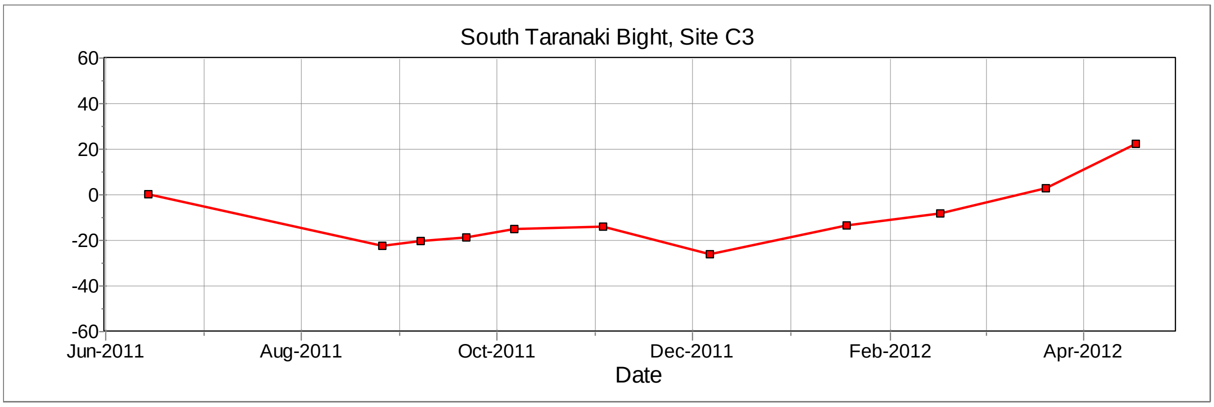
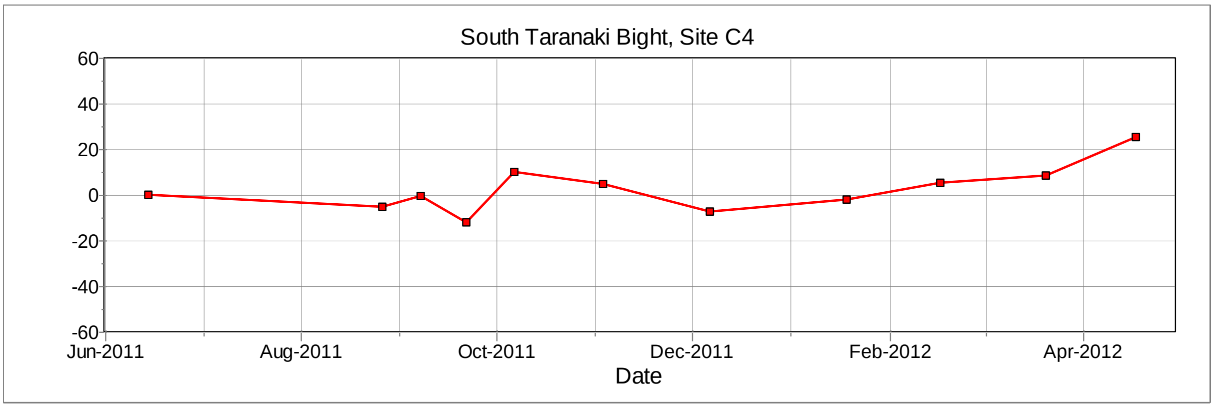
18/01/2012
16/02/2012
20/03/2012
17/04/2012

Waiinu - beach volume change (cut/fill) plots

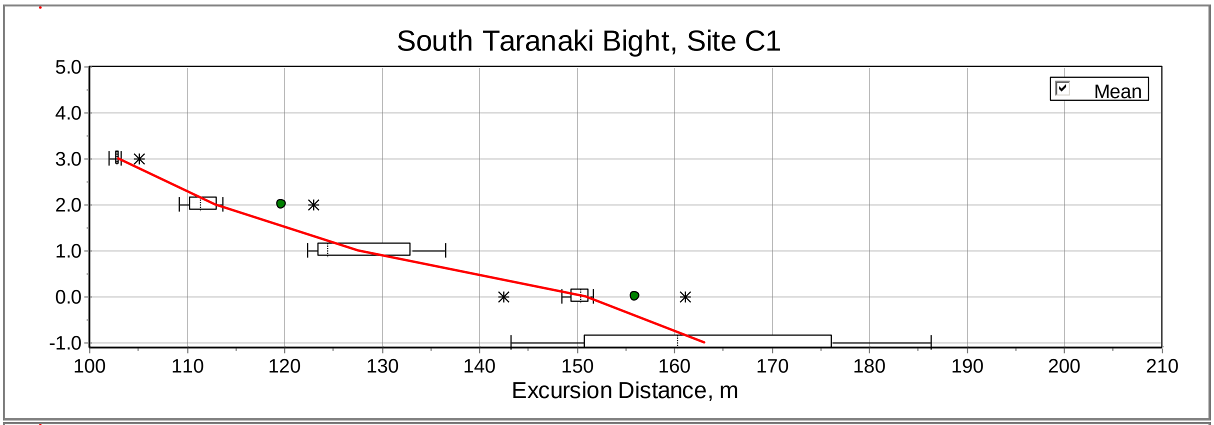


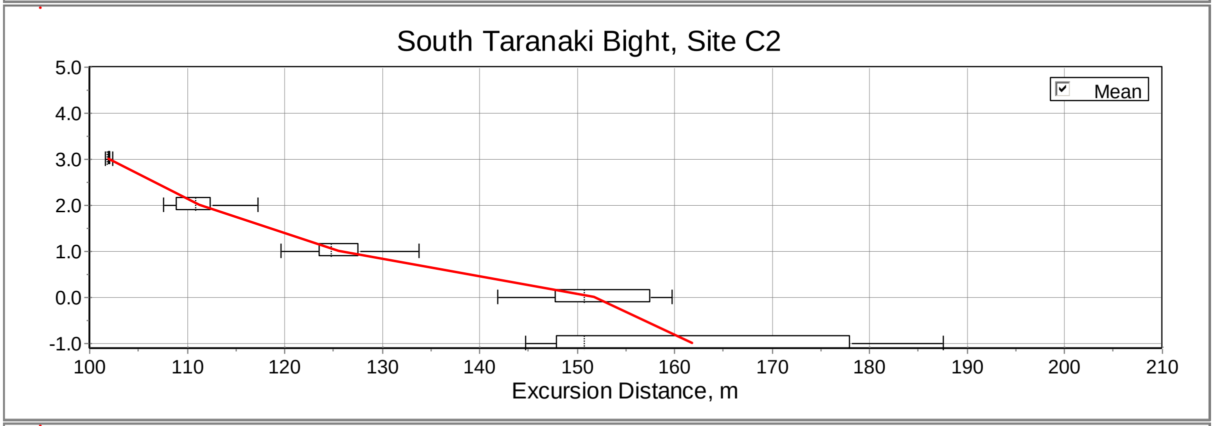


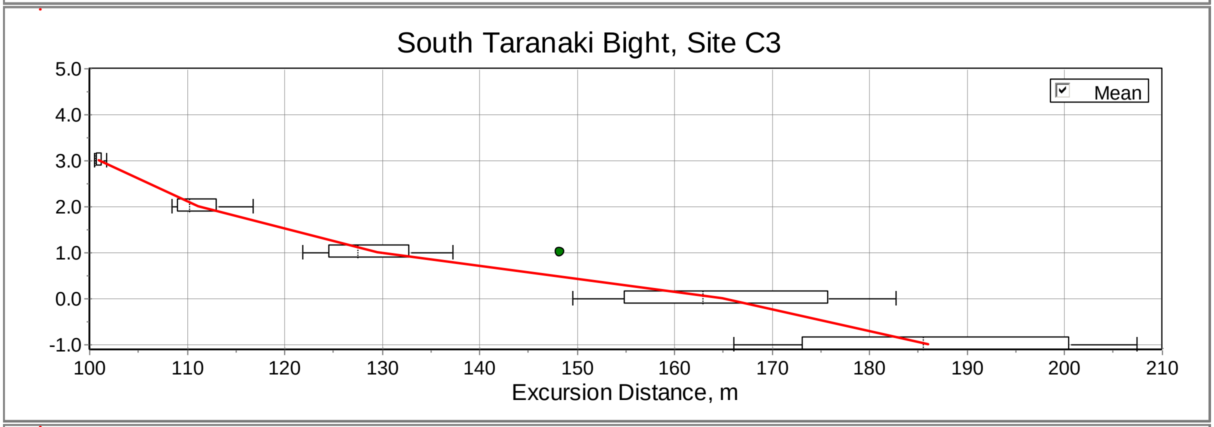


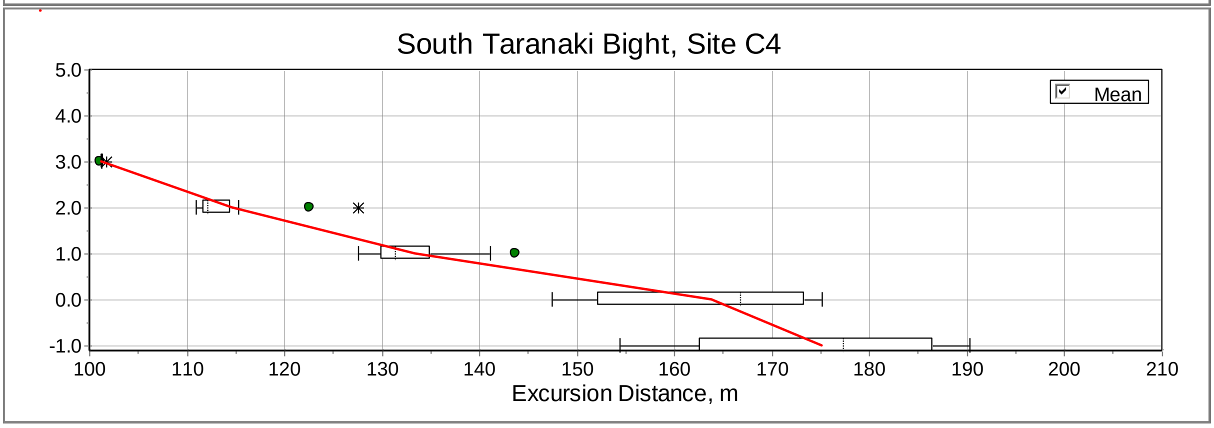


Waiinu - excursion distance plots

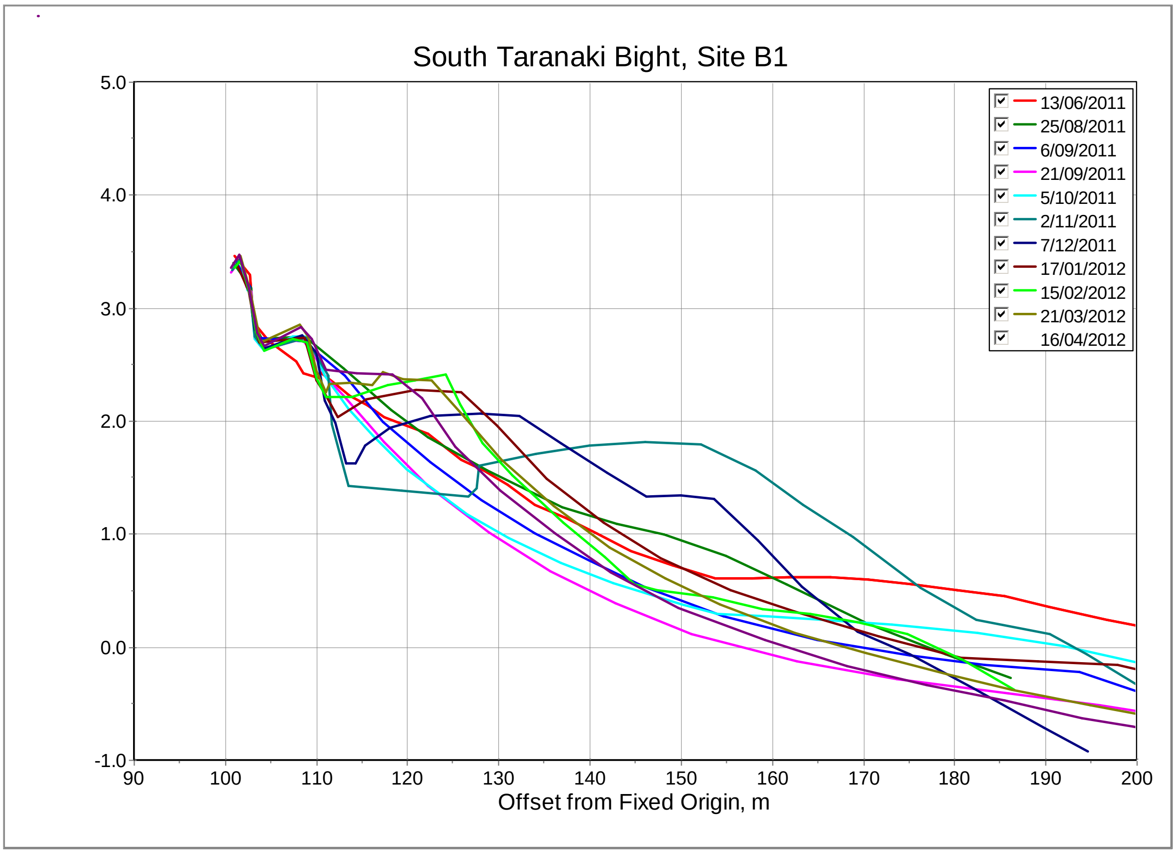


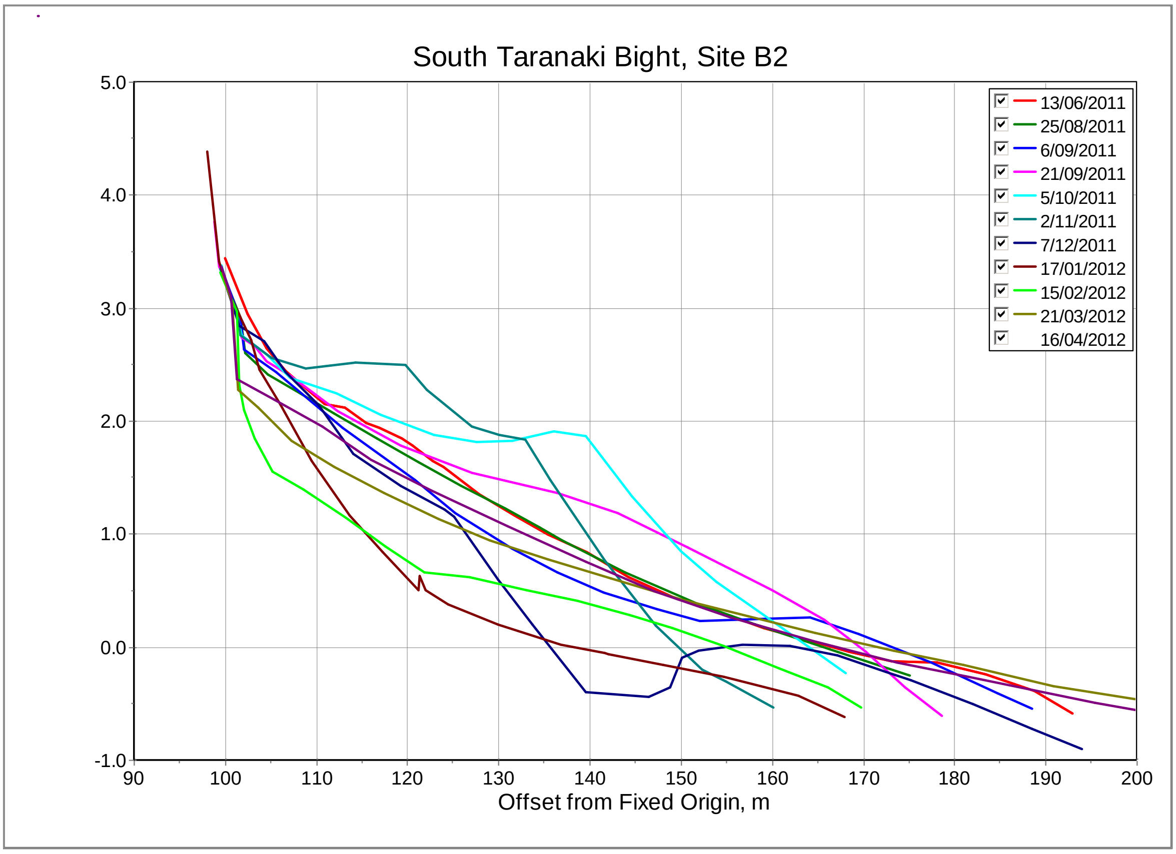


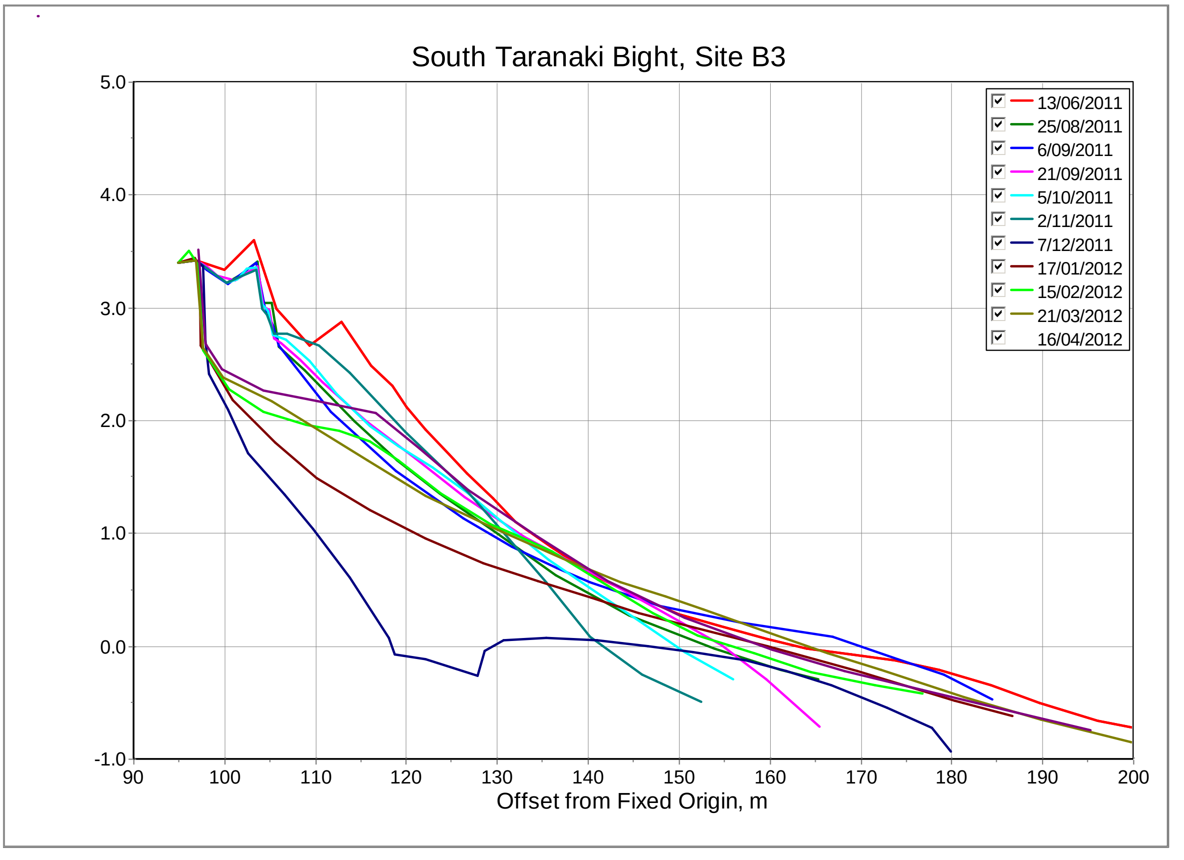




Ototoka – Site B - beach profile plots






South Taranaki Bight, Site B3
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
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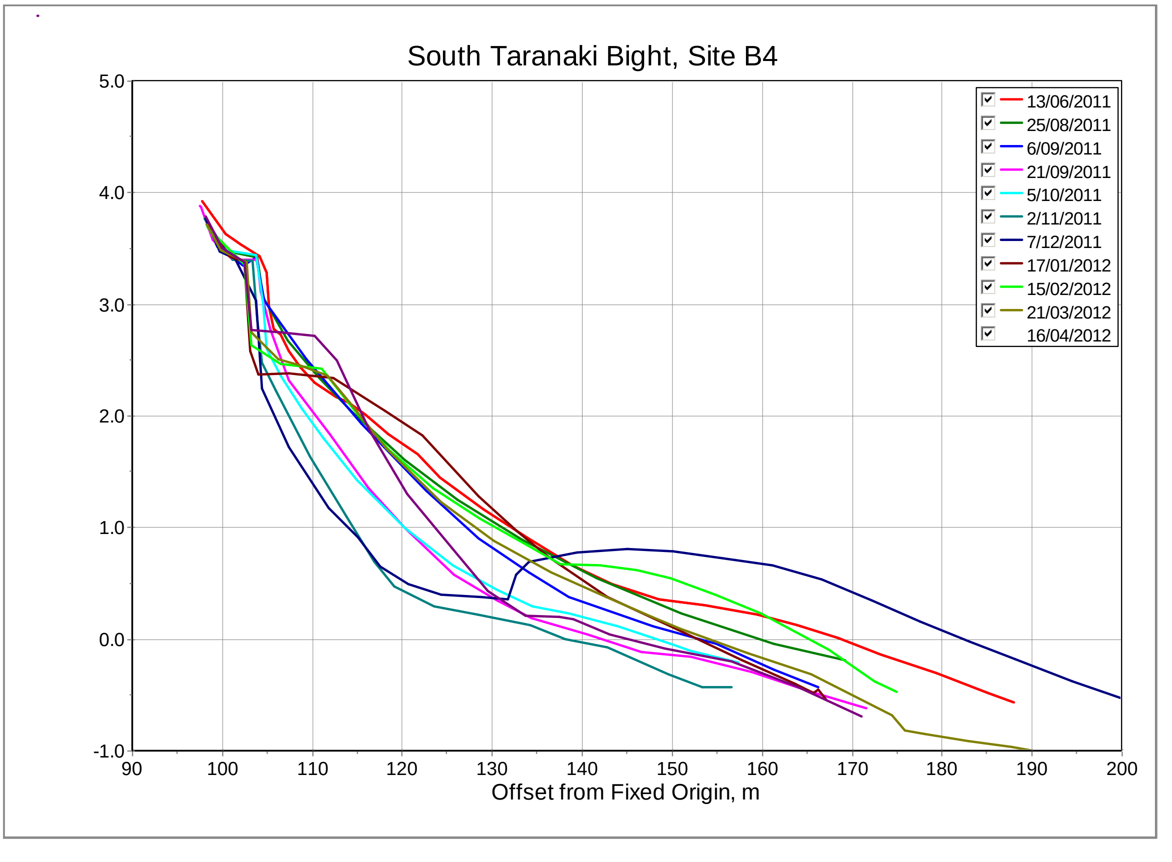
Offset from Fixed Origin, m
13/06/2011
25/08/2011
6/09/2011
21/09/2011
5/10/2011
2/11/2011
7/12/2011
17/01/2012
15/02/2012
21/03/2012
16/04/2012


South Taranaki Bight, Site B4
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4.0
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2.0
1.0
0.0
-1.0
90
100
110
120
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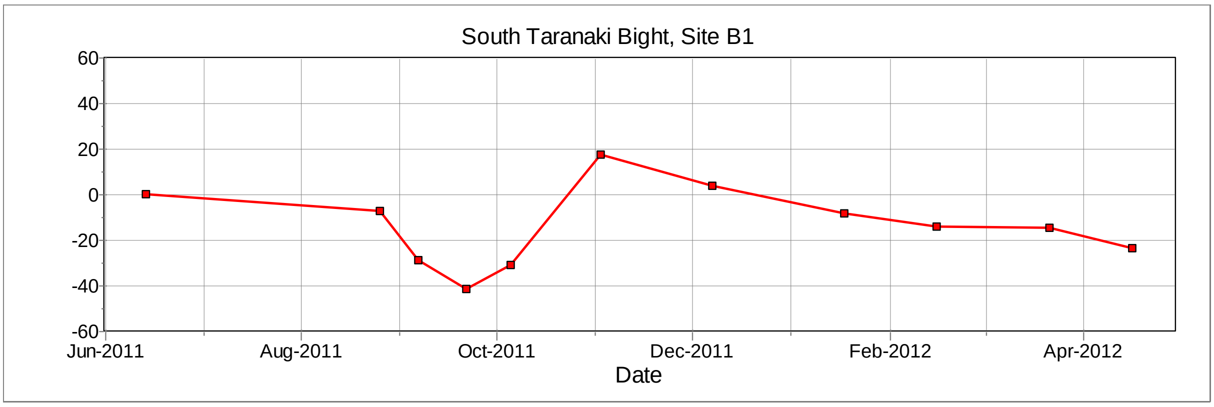
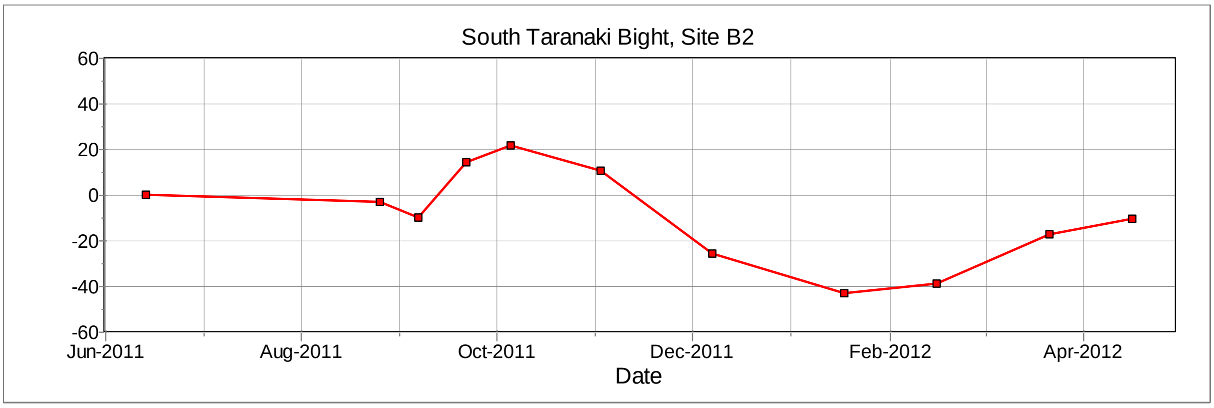
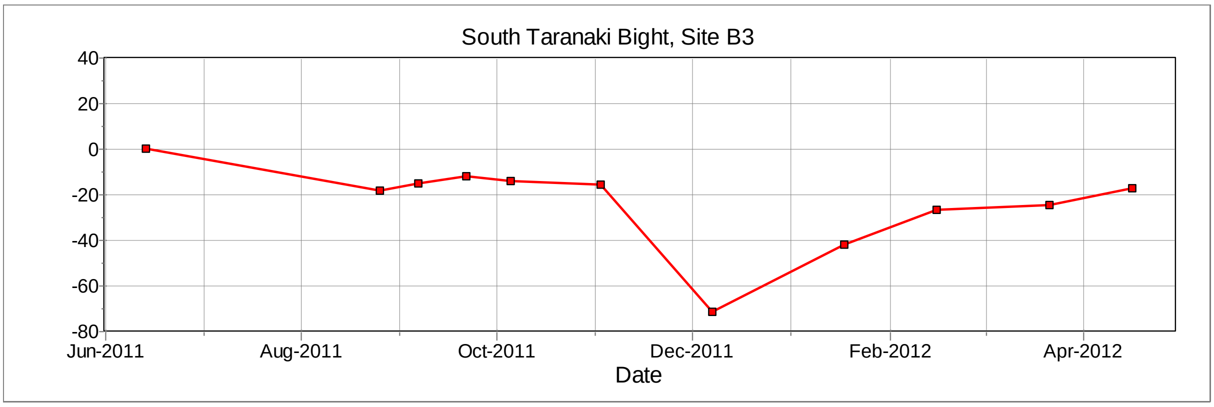
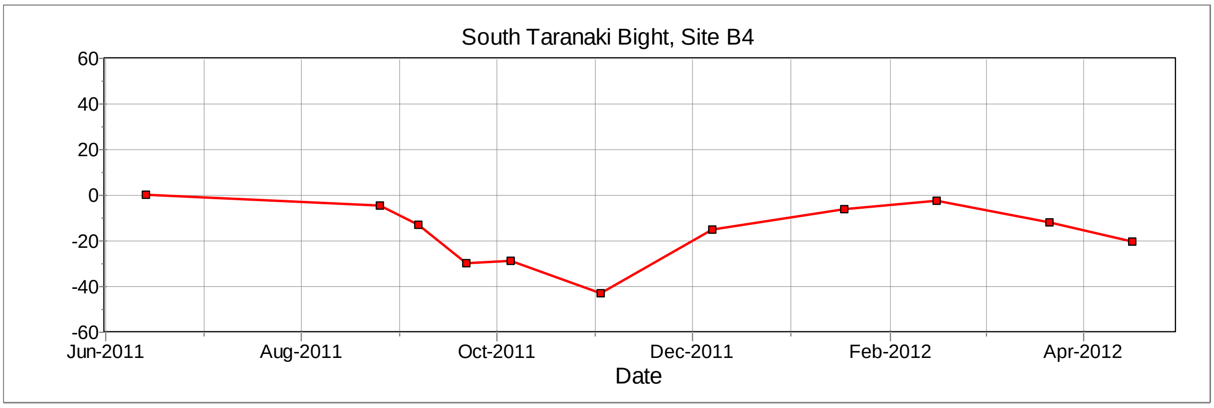
Offset from Fixed Origin, m
13/06/2011
25/08/2011
6/09/2011
21/09/2011
5/10/2011
2/11/2011
7/12/2011
17/01/2012
15/02/2012
21/03/2012
16/04/2012

Ototoka - beach volume change (cut/fill) plots

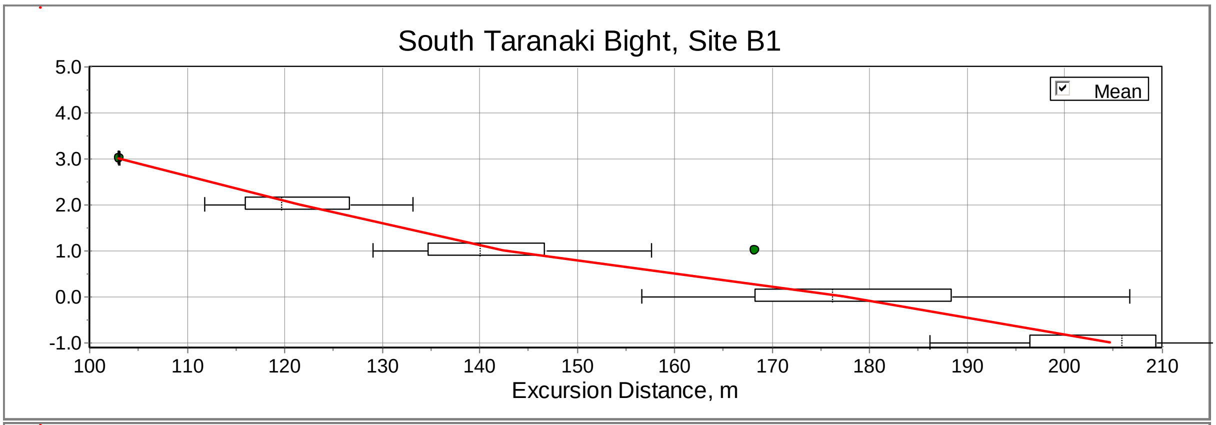


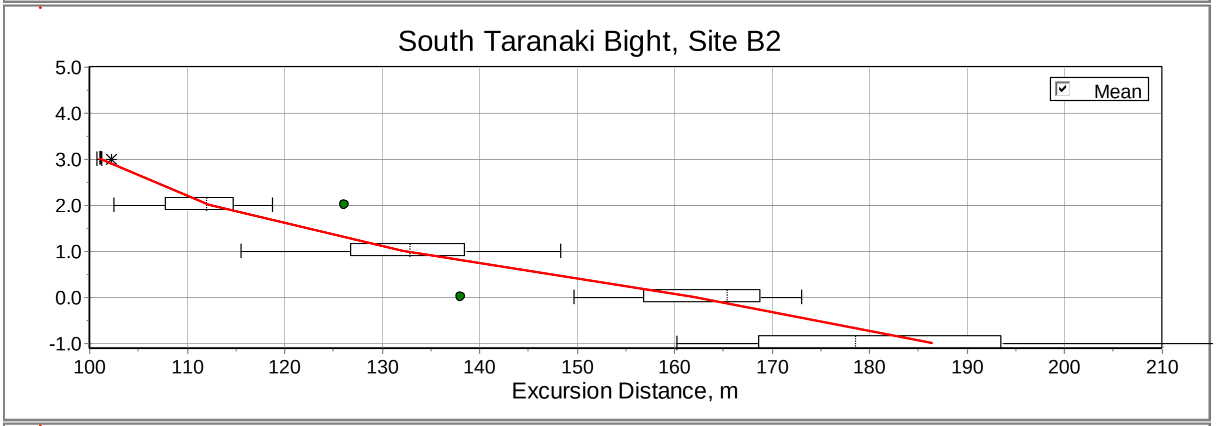


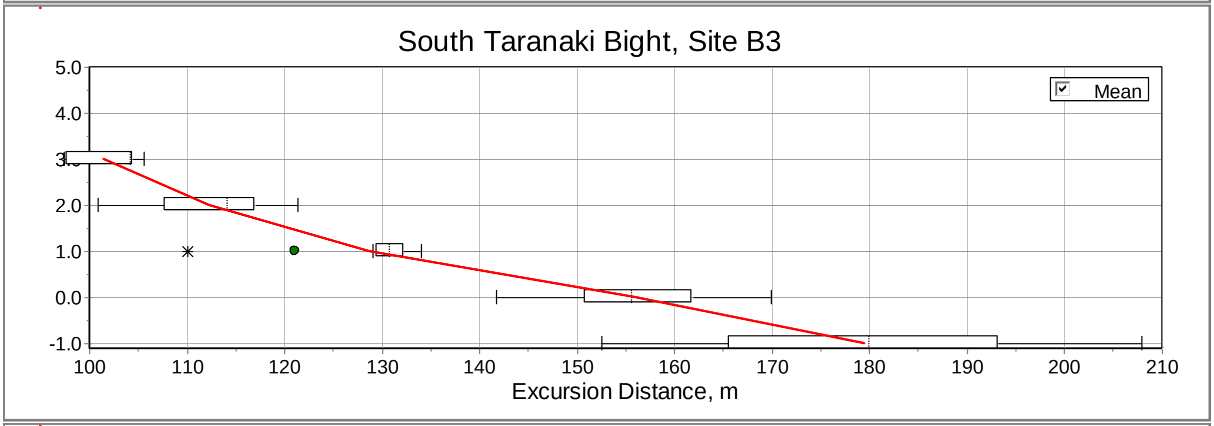


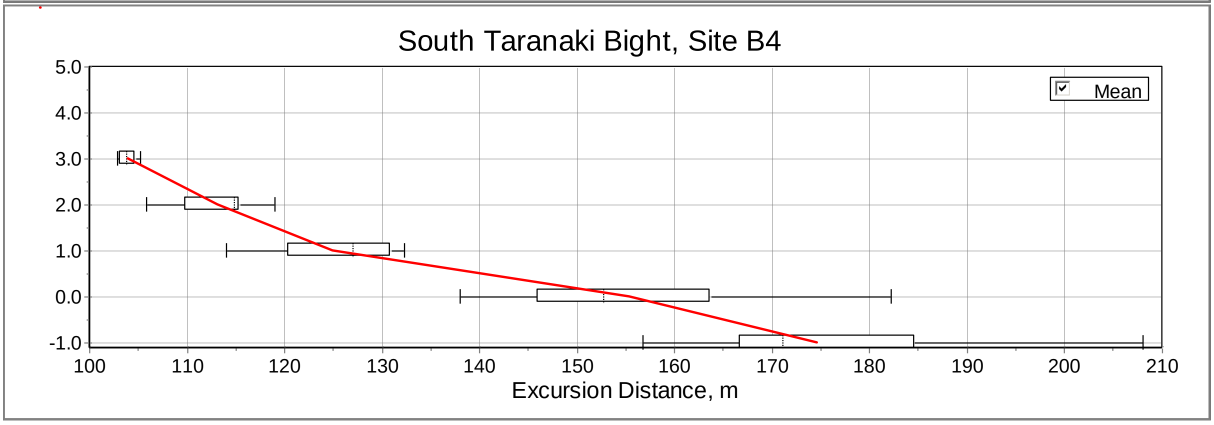


Ototoka - excursion distance plots

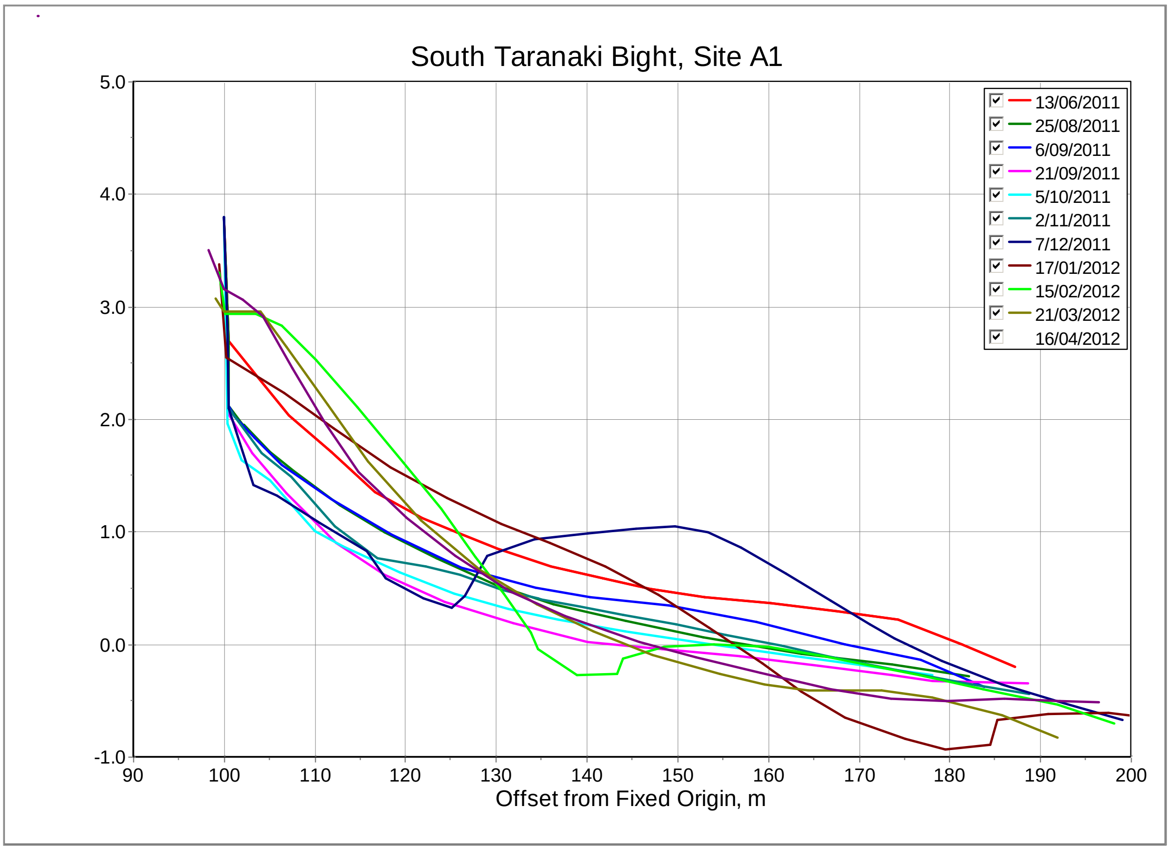


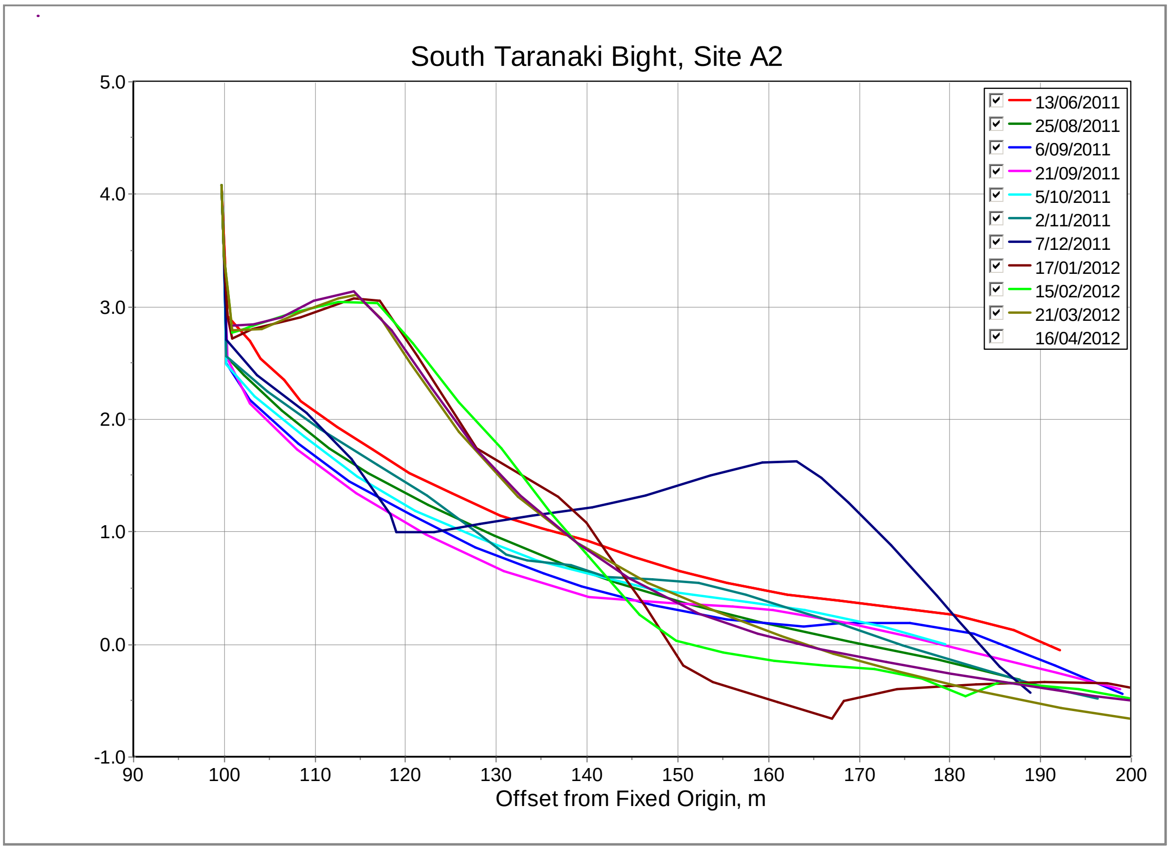


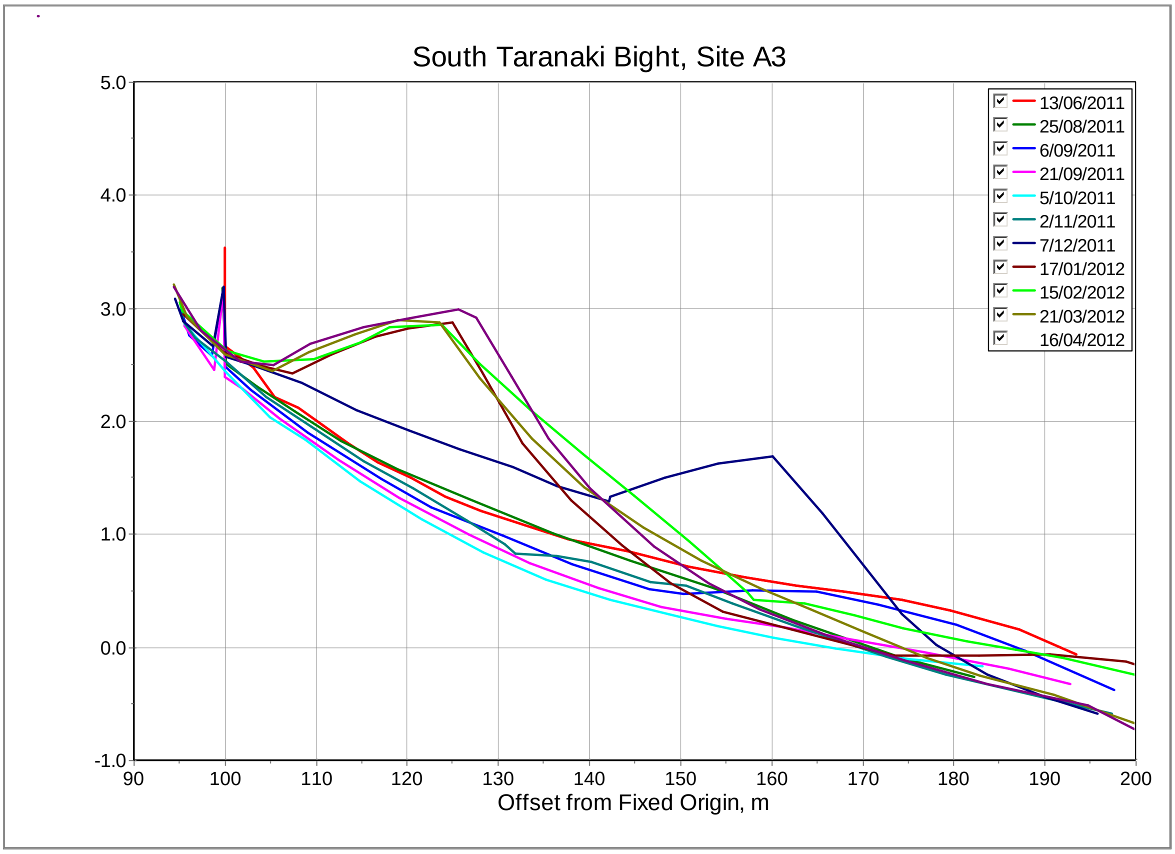




Kai Iwi – Site A - beach profile plots







South Taranaki Bight, Site A3
5.0
4.0
3.0
2.0
1.0
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Offset from Fixed Origin, m
13/06/2011
25/08/2011
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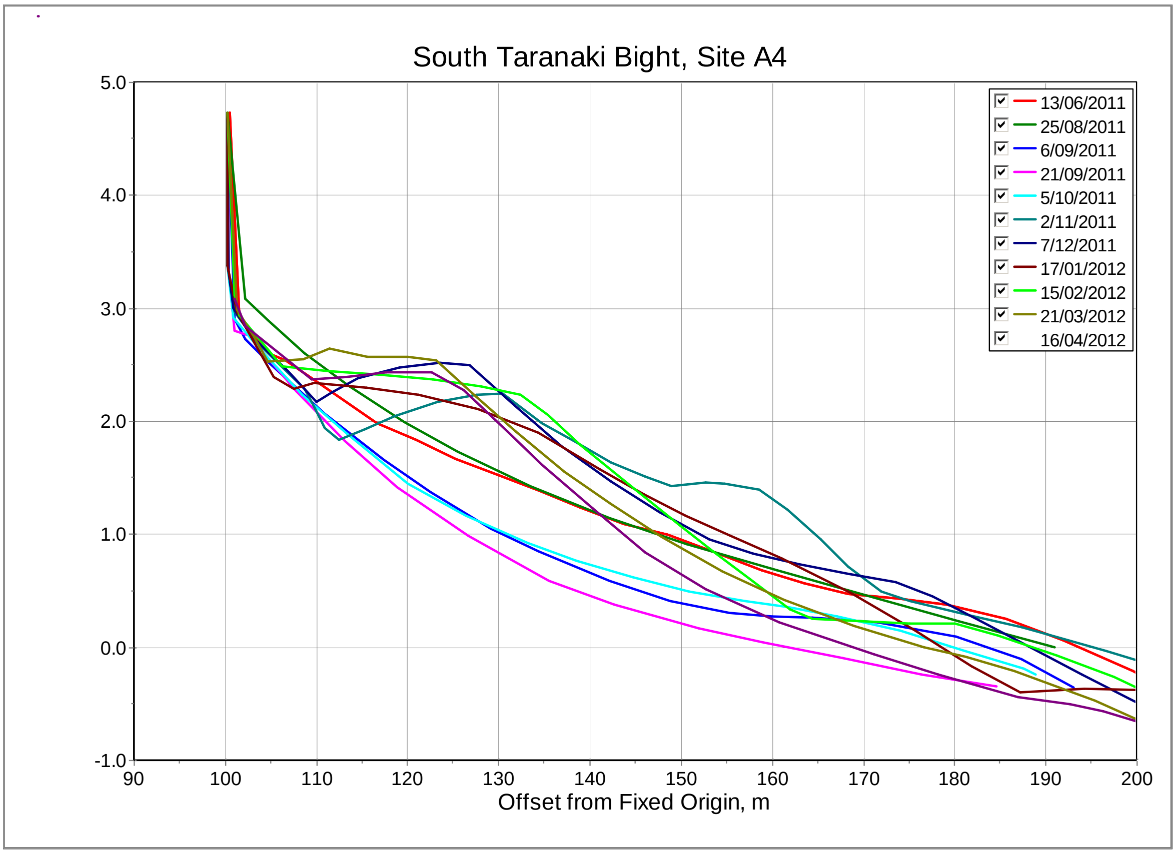
17/01/2012
15/02/2012
21/03/2012
16/04/2012



South Taranaki Bight, Site A4
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3.0
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1.0
0.0
-1.0
90
100
110
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140
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200
Offset from Fixed Origin, m
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6/09/2011
21/09/2011
5/10/2011
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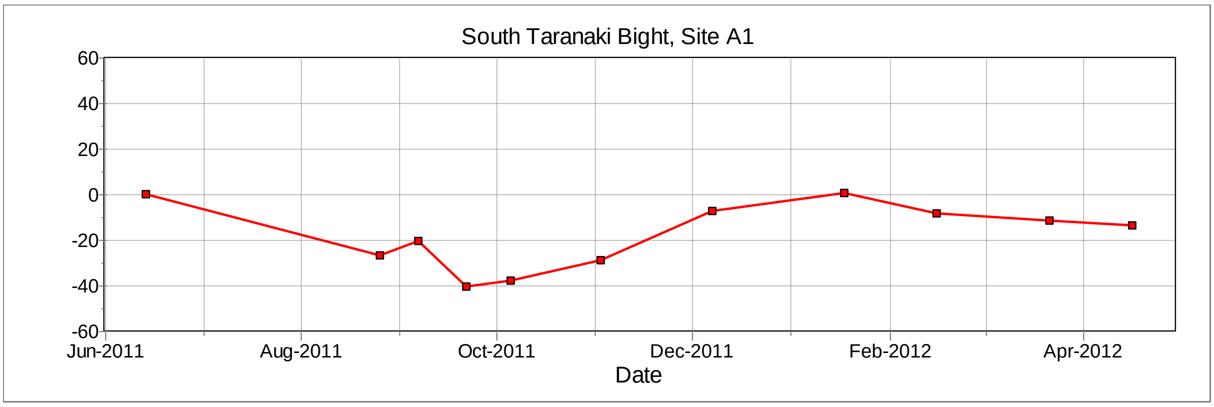
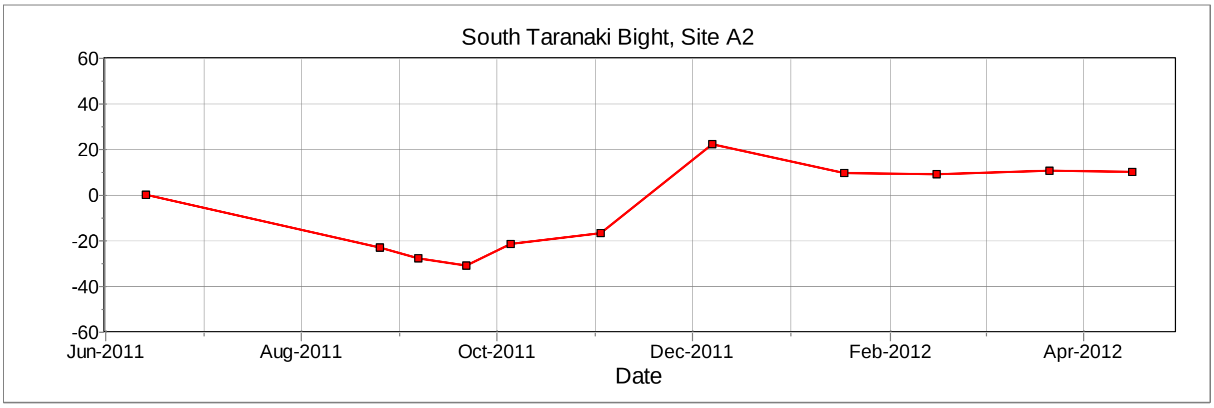
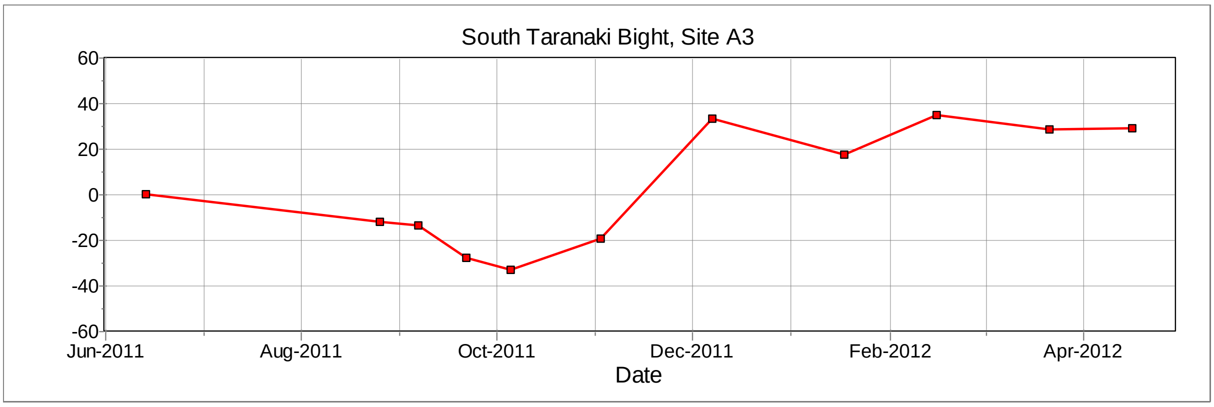
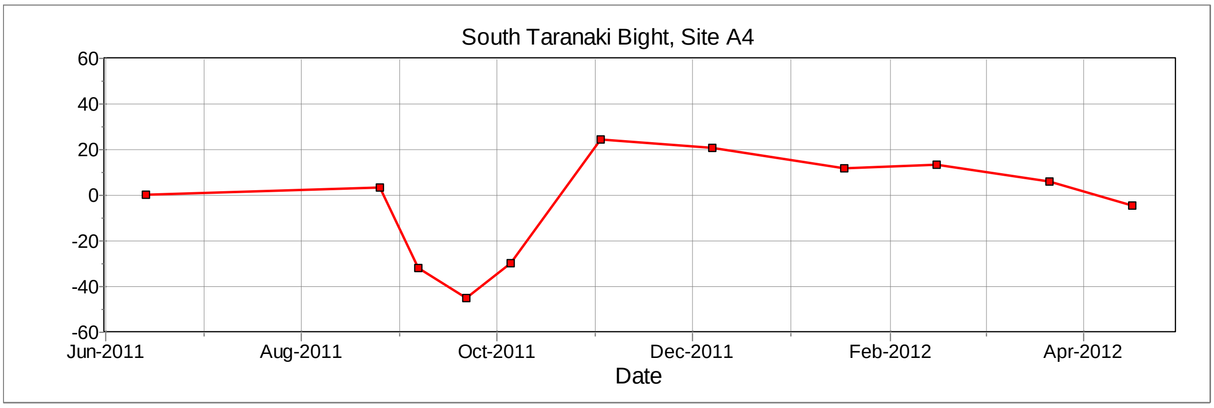
16/04/2012

Kai Iwi - beach volume change (cut/fill) plots

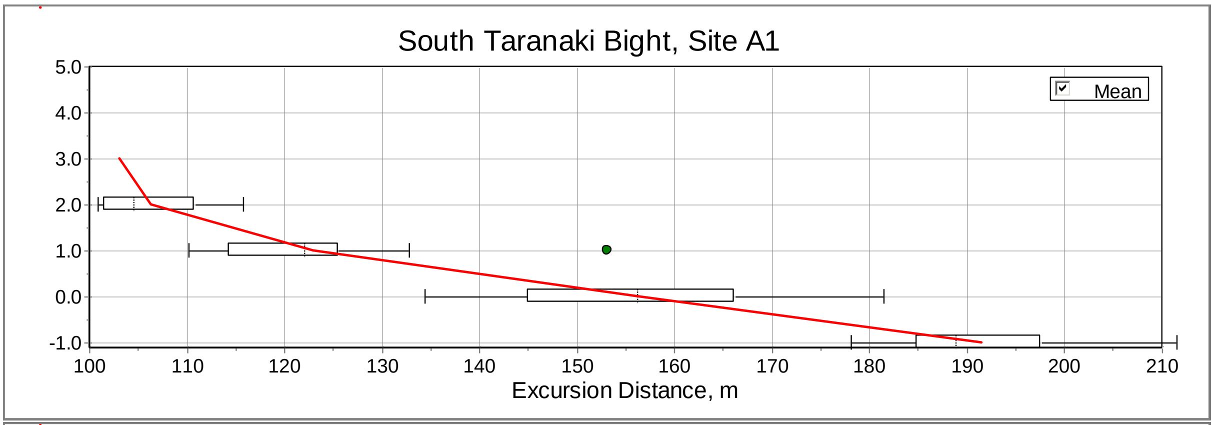


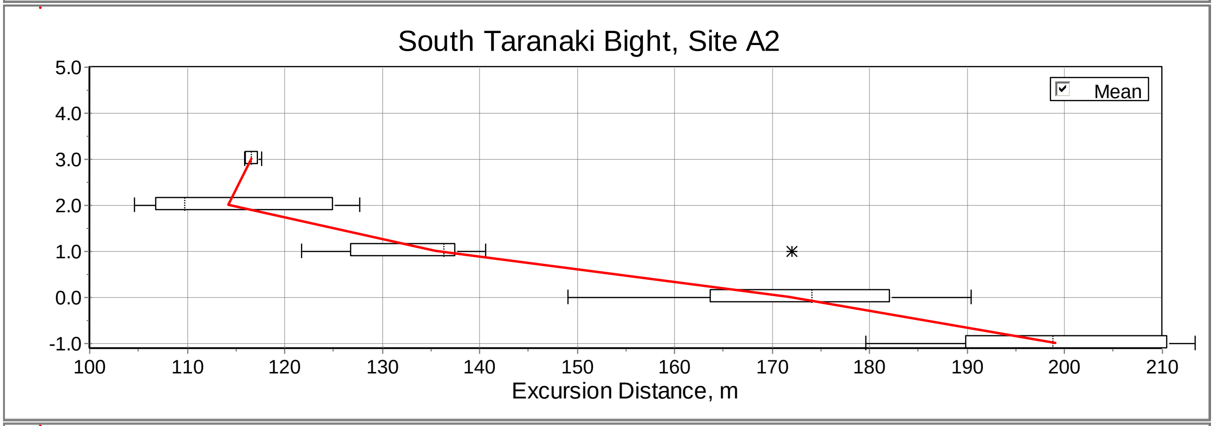


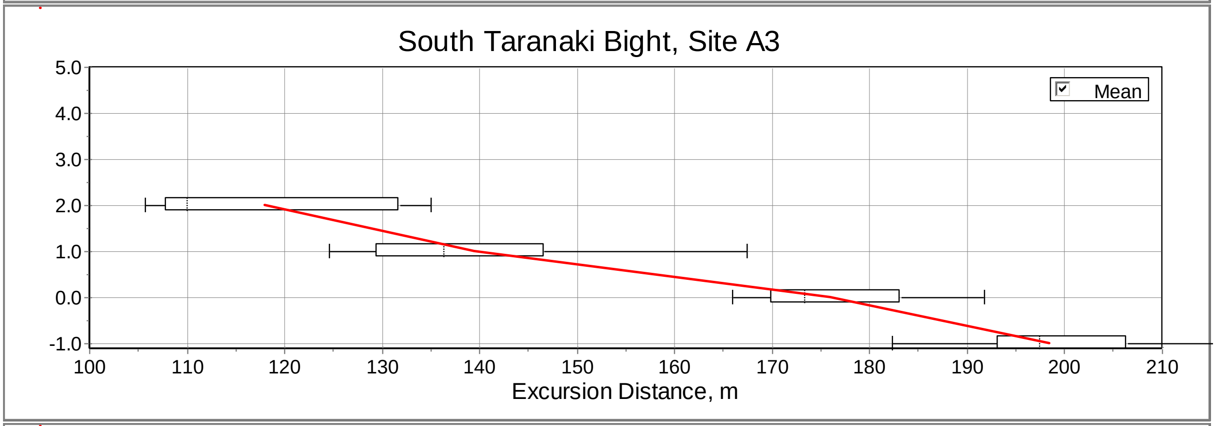


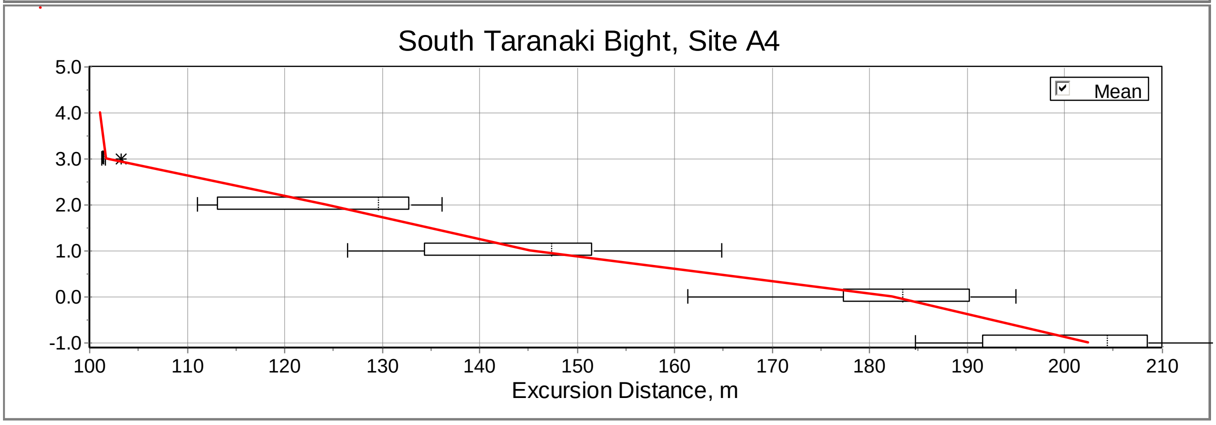


Kai Iwi - excursion distance plots









Appendix B Beach profile summary data extracted from BPAT for all profiles.

Beach profile analysis - Site A Kai Iwi					
11 monthly surveys (13/6/11 to 16/4/12), post storm survey 21 Sept 11					
Profile ID	**A1**	**A2**	**A3**	**A4**	**Average**
Profile data					
Beach width at -0.8m level (m)	110	110	120	120	115.0
Beach width at 0.0m (m)	80	90	90	95	88.8
Beach level fluctuation upper (m)	1.6	1.7	2	1.4	1.7
Beach level fluctuation lower (m)	1.2	2.1	1.6	1.4	1.6
Highest (builtup) beach level (date)	17-Feb-12	17-Feb-12	15-Feb-12	2-Nov-11	
Lowest (cutdown) beach level (date)	21-Sep-11	21-Sep-11	5-Oct-11	21-Sep-11	
Frequency beach berm present (freq n/11)	0	4	4	6	3.5
Frequency swash bars coming ashore (n/11)	6	7	5	6	6.0
Response after Sept storm (cf 6/9 with 21/9/11)	Most erosion	Erosion	Erosion	Erosion	
Cumulative cut/fill data					
Beach most accreted (date)	June11 &Jan12	Jan-12	Dec-April	Nov-11	
Beach most degraded (date)	Sep-11	Sep-11	Sept-oct	Sep-11	
Range of volume fluctuation (m3/m)	41.1	53.1	67.8	69.7	57.9
Net change in beach volume (m3/m)	-13.8	10.3	29.2	-4.7	5.3
Total sand going on+off beach (m3)	196.2	181.5	248.9	190.5	204.3
Ratio Total on/off exchange to Net change (x times)					39
Beach face excursion distance data					
Excursion range at 2m elevation (m)	15	23	29	25	23
Excursion range at 1m elevation (m)	43	50	43	38	44
Excursion range at 0.0m elevation (m)	47	41	26	34	37
Excursion range beach average (m)					35
Excursion beach average : Beach width total factor (%)					30

Beach profile analysis - Site B Ototoka					
11 monthly surveys (13/6/11 to 16/4/12), post storm survey 21 Sept 11					
Profile ID	**B1**	**B2**	**B3**	**B4**	**Average**
Profile data					
Beach width at -1.0m level (m)	130	130	110	100	117.5
Beach width at 0.0m level (m)	110	75	70	80	83.8
Beach level fluctuation upper (m)	1.1	1.5	1.7	1.2	1.4
Beach level fluctuation lower (m)	1.5	1.4	0.6	1.2	1.2
Highest (builtup) beach level (date)	2-Nov-11	5-Oct-11	13-Jun-11	14-Jun-11	
Lowest (cutdown) beach level (date)	21-Sep-11	17-Jan-12	7-Dec-11	2-Nov-11	
Frequency beach berm present (freq n/11)	5	2	4	4	3.8
Freq. swash bars coming ashore on lower beach (freq n/11)	5	4	3	6	4.5
Response after Sept storm (cf 6/9 with 21/9/11)	Erosion	Accretion	Accretion	Erosion	
Cumulative cut/fill data					
Beach most accreted (date)	Nov-11	Oct-11	Jun-11	july11, feb12	
Beach most degraded (date)	Sep-11	Jan-12	Dec-11	Nov-11	
Range of volume fluctuation (m3/m)	58.6	60.4	71.4	42.9	58.3
Net change in beach volume (m3/m)	23.7	-10.5	-17.3	-20.4	-6.1
Total sand going on+off beach (m3)	190.7	195.3	258.1	176.1	205.1
Ratio Total on/off exchange : Net change (x times)					-33
Beach face excursion distance					
Excursion range at 2m elevation (m)	21	24	20	13	20
Excursion range at 1m elevation (m)	39	33	24	18	29
Excursion range at 0.0m elevation (m)	50	35	28	44	39
Excursion range beach average (m)					29
Excursion beach average : Beach width total factor (%)					25

Beach profile analysis - Site C Waiinu					
11 monthly surveys (14/6/11 to 17/4/12), post storm survey 21 Sept 11					
Profile ID	**C1**	**C2**	**C3**	**C4**	**Average**
Profile data					
Beach width at -0.6m (m)	90	95	110	105	100.0
Beach width at 0.0m (m)	70	65	85	80	75.0
Beach level fluctuation upper (m)	0.8	1.0	0.9	0.8	0.9
Beach level fluctuation lower (m)	0.6	0.6	0.7	0.6	0.6
Highest (builtup) beach level (date)	26-Aug-11	3-Nov-11	17-Apr-11	17-Apr-11	
Lowest (cutdown) beach level (date)	21-Nov-11	17-Apr-11	6-Dec-11	22-Sep-11	
Frequency beach berm present (freq n/11)	5	3	2	5	3.8
Freq. swash bars coming ashore on lower beach (freq n/11)	4	4	5	3	4.0
Response after Sept storm (cf 6/9 with 21/9/11)	someErosion	Neutral	Accretion	mostErosion	
Cumulative cut/fill data					
Beach most accreted (date)	Aug, Nov, Apr12	Nov-11	Apr-12	Apr-12	
Beach most degraded (date)	Sept, Feb12	Sept, Oct, April	Aug11, Dec11	Sep-11	
Range of volume fluctuation (m3/m)	26.5	20.2	48.8	27.4	30.7
Net change in beach volume (m3/m)	-0.1	-7.4	22.3	25.4	10.1
Total sand going on+off beach (m3)	98.7	57.2	164.4	81.5	100.5
Ratio Total on/off exchange : Net change (x times)					10
Beach face excursion distance data					
Excursion range at 2m elevation (m)	14	10	8	17	12
Excursion range at 1m elevation (m)	14	14	26	16	18
Excursion range at 0.0m elevation (m)	19	18	32	28	24
Excursion range beach average (m)					18
Excursion beach average : Beach width total factor (%)					18

Beach profile analysis -Site D Waverley					
11 monthly surveys (14/6/11 to 17/4/12), post storm survey 22 Sept 11					
Profile ID	**D1**	**D2**	**D3**	**D4**	**Average**
Profiles					
Beach width at -0.8m (m)	105	110	115	105	108.8
Beach width at 0.0m (m)	75	80	70	55	70.0
Beach level fluctuation upper (m)	0.8	2.0	1.4	1.3	1.4
Beach level fluctuation lower (m)	1.3	1.4	0.8	0.9	1.1
Highest (builtup) beach level (date)	3-Nov-11	20-Mar-11	22-Sep-11	3-Nov-11	
Lowest (cutdown) beach level (date)	26-Aug-11	14-Jun-11	14-Jun-11	22-Sep-12	
Frequency beach berm present (freq n/11)	3	4	1	0	2.0
Freq. swash bars coming ashore on lower beach (n/11)	5	3	5	4	4.3
Response after Sept storm (cf 7/9 with 22/9/11)	Neutral	Erosion	Erosion	Erosion	
Cumulatve cut/fill data					
Beach most accreted (date)	Nov11, Jan-Mar	Mar-11	Dec-11	Sep-11	
Beach most degraded (date)	Aug11, Dec11	Jun-11	Sep-11	Feb-12	
Range of volume fluctuation (m3/m)	24.4	34.7	46.2	50.4	38.9
Net change in beach volume (m3/m)	-3.1	21.9	-7.8	7.7	4.7
Total sand going on+off beach (m3)	72.5	156.9	109.9	99	109.6
Ratio Total on/off exchange : Net change (x times)					23
Beach face excursion distance data					
Excursion range at 2m elevation (m)	10	17	13		10
Excursion range at 1m elevation (m)	12	26	30		17
Excursion range at 0.0m elevation (m)	29	30	29		22
Excursion range beach average (m)					16
Excursion beach average : Beach width total factor (%)					15

Beach profile analysis - Site E Patea					
11 monthly surveys (14/6/11 to 17/4/12), post storm survey 22 Sept 11					
Profile ID	**E1**	**E2**	**E3**	**E4**	**Average**
Profile data					
Beach width at -0.6m (m)	110	110	90	110	105.0
Beach width at 0.0m (m)	90	80	65	60	73.8
Beach level fluctuation upper (m)	0.8	1.0	1.0	1.2	1.0
Beach level fluctuation lower (m)	1.2	1.5	1.8	2.0	1.6
Highest (builtup) beach level (date)	6-Oct-11	6-Oct-11	26-Aug-11	26-Aug-11	
Lowest (cutdown) beach level (date)	18-Jan-12	6-Dec-11	17-Mar-12	6-Oct-11	
Frequency beach berm present (freq n/11)	2	0	1	1	1.0
Freq. swash bars coming ashore on lower beach (n/11)	3	4	4	3	3.5
Response after Sept storm (cf 7/9 with 22/9/11)	Accretion	mostlyerosion	Erosion	mostErosion	
Cumulative cut/fill data					
Beach most accreted (date)	Oct-Nov, Feb12	Oct-11	Aug-11	Aug-11	
Beach most degraded (date)	Jan-12	Dec11, Jan12	Jun, Oct, Apr	Sept-Oct	
Range of volume fluctuation (m3/m)	41.6	28.6	63.6	73.3	51.8
Net change in beach volume (m3/m)	-9.9	-16.2	-5.4	-32.1	-15.9
Total sand going on+off beach (m3)	100.6	108	227.5	241.7	169.5
Ratio Total on/off exchange : Net change (x times)					-11
Beach face excursion distance					
Excursion range at 2m elevation (m)	16	13	22	26	19
Excursion range at 1m elevation (m)	21	18	25	28	23
Excursion range at 0.0m elevation (m)	20	23	23	23	22
Excursion range beach average (m)					22
Excursion beach average : Beach width total factor (%)					20

Beach profile analysis - Site F Manawapou					
11 monthly surveys (15/6/11 to 18/4/12), post storm survey 22 Sept 11					
Profile ID	**F1**	**F2**	**F3**	**F4**	**Average**
Profile data					
Beach width at -1.3m (m)	75	85	100	105	91.3
Beach width at 0.0m (m)	50	50	20	25	36.3
Beach level fluctuation upper (m)	0.6	1.4	1.3	1.8	1.3
Beach level fluctuation lower (m)	1.0	1.2	0.7	1.3	1.1
Highest (builtup) beach level (date)	8-Sep-11	17-Feb-12	8-Sep-11	18-Apr-12	
Lowest (cutdown) beach level (date)	5-Dec-11	22-Sep-11	9-Jan-12	15-Dec-11	
Frequency beach berm present (freq n/11)	2	3	3	0	2.0
Freq. swash bars coming ashore on lower beach (n/11)	3	3	3	2	2.8
Response after Sept storm (cf 7/9 with 22/9/11)	Erosion	Erosion	Erosion	Erosion	
Cumulative cut/fill data					
Beach most accreted (date)	Oct-11	Feb-12	Sep-11	8Sept, 18April	
Beach most degraded (date)	June-Aug	Sept-Jan12	Feb-Mar12	Dec-11	
Range of volume fluctuation (m3/m)	114.6	28.2	19.2	19.0	45.3
Net change in beach volume (m3/m)	78.9	9.4	-0.5	15.0	25.7
Total sand going on+off beach (m3)	805.8	77.6	47.6	55.0	246.5
Ratio Total on/off exchange : Net change (x times)					10
Beach face excursion distance					
Excursion range at 2m elevation (m)	5	9	0	3	4
Excursion range at 1m elevation (m)	8	13	8	9	10
Excursion range at 0.0m elevation (m)	26	32	14	21	23
Excursion range beach average (m)					12
Excursion beach average : Beach width total factor (%)					14

Beach profile analysis - Site G Hawera					
11 monthly surveys (15/6/11 to 18/4/12), post storm survey 23 Sept 11					
Profile ID	**G1**	**G2**	**G3**	**G4**	**Average**
Profile data					
Beach width at -1.2m (m)	60	130	65	75	82.5
Beach width at 0.0m (m)	35	30	43	40	37.0
Beach level fluctuation upper (m)	0.6	0.4	0.8	1.0	0.7
Beach level fluctuation lower (m)	0.7	0.2	0.7	1.2	0.7
Highest (builtup) beach level (date)	19-Mar-12	23-Sep-11	23-Sep-11	23-Sep-11	
Lowest (cutdown) beach level (date)	15-Jun-11	18-Apr-12	18-Apr-12	18-Apr-12	
Frequency beach berm present (freq n/11)	0	2	3	1	1.5
Freq. swash bars coming ashore on lower beach (n/11)	0	2	2	1	1.3
Response after Sept storm (cf 7/9 with 2/9/11)	Erosion	Accretion	Accretion	Neutral	
Cumulative cut/fill data					
Beach most accreted (date)	19-Mar-12	23-Sep-11	Sept, Dec11	23-Sep-11	
Beach most degraded (date)	15-Jun-11	18-Apr-12	Feb-April	18-Apr-12	
Range of volume fluctuation (m3/m)	19.2	6.6	22.4	18.6	16.7
Net change in beach volume (m3/m)	8.9	-2.4	-19.6	-15.9	-7.3
Total sand going on+off beach (m3)	91.7	15.8	102.8	58.2	67.1
Ratio Total on/off exchange : Net change (x times)					-9
Beach face excursion distance					
Excursion range at 2m elevation (m)	4	1	9	8	6
Excursion range at 1m elevation (m)	9	2	11	10	8
Excursion range at 0.0m elevation (m)	8	2	17	17	11
Excursion range beach average (m)					8
Excursion beach average : Beach width total factor (%)					10

Beach profile analysis - Site H Ohawe					
11 monthly surveys (15/6/11 to 18/4/12), post storm survey 23 Sept 11					
Profile ID	**H1**	**H2**	**H3**	**H4**	**Average**
Profile data					
Beach width at -1.2m (m)	70	70	130	115	96.3
Beach width at 0.0m (m)	48	43	47	50	47.0
Beach level fluctuation upper (m)	1.4	0.8	1.4	0.8	1.1
Beach level fluctuation lower (m)	0.7	1.0	0.7	0.8	0.8
Highest (builtup) beach level (date)	19-Mar-12	18-Apr-12	19-Apr-12	15-Jun-11	
Lowest (cutdown) beach level (date)	15-Jun-11	15-Jun-11	19-Jan-12	23-Sep-11	
Frequency beach berm present (freq n/11)	0	1	4	1	1.5
Freq. swash bars coming ashore on lower bch (n/11)	5	2	4	6	4.3
Response after Sept storm (cf 7/9 with 22/9/11)	Erosion	Erosion	Erosion	Erosion	
Cumulative cut/fill data					
Beach most accreted (date)	18-Apr-12	Aug11, Apr12	Apr-12	Aug-11	
Beach most degraded (date)	Jun11, Oct11	Jun11, Oct-Dec	Jun11, Nov-Jan	Oct-Jan12	
Range of volume fluctuation (m3/m)	46.1	24.2	31.9	21.5	30.9
Net change in beach volume (m3/m)	46.1	24.2	31.9	-9.5	23.2
Total sand going on+off beach (m3)	215.1	97.2	126	109.3	136.9
Ratio Total on/off exchange : Net change (x times)					6
Beach face excursion distance data					
Excursion range at 2m elevation (m)	17	9	25	5	14
Excursion range at 1m elevation (m)	16	12	12	9	12
Excursion range at 0.0m elevation (m)	9	12	14	21	14
Excursion range beach average (m)					13
Excursion beach average : Beach width total factor (%)					14